TREES IN THE URBAN LANDSCAPE

Prepared by
the Trees in the Urban Landscape Committee

TABLE OF CONTENTS

	Page
INTRODUCTION	1
THE VALUE OF STREET TREES	2
GENERAL GROWTH CHARACTERISTICS OF TREES	4
Branch and Crown Development	4
Root Development	4
THE COMPONENTS OF A SUCCESSFUL STREET TREE PROGRAM	7
Planning	7
Public Involvement	7
Interdepartmental Cooperation	7
Coordination of Utility and Street Tree Planning	7
Inventories	9
Design 9	
Developing a Street Tree Planting Plan	9
General Design Concepts	9
Selection of Street Trees	9
Location of Street Trees	9
Utility Design and Street Trees	10
Underground Utilities	10
Roads and Sidewalks	12
Implementation (Planting)	13
Planting Stock	13
Pruning	13
Planting Methods	13
Planting Holes	13
Fertilization	13
Watering	13
Staking, Guying and Wrapping	16
Routine Maintenance	16
General Considerations	16
Life Cycle Costing	18
Specific Tasks	18
Pruning	18
Control of Suckering	18
Watering	18
Fertilizing	20
Wound Treatments	20
Insect and Disease Control	20
Prevention of Vandalism	20
Prevention of Maintenance Damage	20

Utility Maintenance 21
Block-out 21
Clean-out 21
Snuff-out 21

APPENDICES

A. Street Tree Species for Alberta 22

B. Spacing and Setback Recommendations for Street Trees 36

C. Agencies and Organizations that can Assist Street Tree Programs 37

D. Members of the Trees in the Urban Landscape Committee 38

REFERENCES 39

INTRODUCTION

Street trees can make a major contribution to the quality of life in Alberta communities in many ways. The purpose of this publication is to describe street tree program planning, design, implementation and maintenance principles that can be applied in Alberta communities to improve their streetscapes. It is hoped that these principles will be of interest to municipal councils, planning commissions, and interested citizens, as well as to the planners and managers of urban municipalities.

Although trees have several types of settings in an urban area, including parks and other public property as well as on private land, the focus of this publication is on street trees. Street trees are those that grow within the right-of-way of streets; more specifically, in one of the three possible situations:

1. The strip of turf between the curb (or edge of the street surface) and the sidewalk.
2. The area between the sidewalk or the edge of the street and the property line.
3. Medians within the street.

This publication was prepared by the members of the Trees in the Urban Landscape Committee, which was created in response to the need to gain technical information regarding the special needs of urban trees, particularly street trees. The terms of reference for the Committee were:

- to develop guidelines for the planting of trees with extensive root systems in urban situations
- to develop guidelines for appropriate plant materials for urban landscape
- to develop communication guidelines for the introduction and use of new plant materials in urban situations
- to develop guidelines for tree hardiness in urban situations,
  i.e., growth potential vs. mortality rate
- to discuss life cycle costing regarding the use of plant material in urban situations.

The energies of the committee were directed primarily to municipal concerns regarding:

- the promotion of the positive aspects of plant materials in the urban situation
- the promotion of good horticultural practices in the urban situation
- a survey of the problems of existing trees in urban centres.

The work of the committee progressed over a three year period, with financial assistance from Alberta Agriculture, the Urban Development Institute, the Landscape Alberta Nursery Trades Association, and the Alberta Association of Landscape Architects. The membership of the committee is listed in Appendix D.

THE VALUE OF STREET TREES

The urban environment easily can, and frequently does, manifest itself as a cold and sterile place not conducive to human health and happiness. Approximately 80 percent of Alberta's 2.3 million population resides in urban municipalities, so it is important that positive steps be taken to enhance the urban environment.

Street trees provide many benefits to urban areas, and these benefits can be either tangible functional benefits, or less-tangible aesthetic benefits, which together can ultimately result in economic benefits.

One of the most important functional benefits of street trees is climate control. Trees can have the effect of moderating air temperature; the provision of shade during the heat of the summer being the most obvious means of accomplishing this. Trees can shield people, structures and the ground surface from the direct heat of the sun during the day, and this shading can continue its benefit during the night, as structures and the ground surface which have had reduced heat absorption during the day will not re-radiate so much heat at night, allowing the air to be comfortably cool. Trees can also directly help to reduce daily temperature fluctuations, because they absorb heat during the day and release heat at night. Of course, in Alberta's cold winters, it is desirable to maximize the heating potential of solar energy, and here deciduous trees can be of greatest benefit, for they can provide shade in summer, while allowing sunlight through in winter. Trees can help to reduce the damage and inconvenience caused by wind by acting as a windbreak, and in winter can also help to reduce snow drifting by generally reducing wind speeds throughout the community. In summer, trees can help to increase air humidity as a result of a combination of reducing air temperature and by giving off moisture from the leaves, through the process of evapotranspiration.

In addition to climate control, trees can also contribute to air quality. This can occur, in part, as a result of the oxygen generated by the leaves, as a byproduct of photosynthesis. The oxygen added to the atmosphere by vegetation on a global scale is, of course, essential to the existence of air-breathing life. But on a smaller scale, the oxygen generated by trees can have an immediate benefit by reducing the harmful effects of air pollution. Trees also reduce air pollution by absorbing sulphur dioxide and ozone, and by filtering dust and other particulate matter out of the air.

A further benefit of trees is that they can serve to reduce visual pollution, that is, by screening unsightly land uses or developments in communities. It must be recognized that screening by trees may take several years to become effective, however, trees can ultimately be superior to architectural screening (that is, fences) because they also contribute colour, texture, and life to the landscape. The visual screening provided by trees makes another major contribution to the quality of life in the urban environment, for nowhere else do people more keenly feel the need for privacy.

Another major detriment to life in urban areas is noise, and trees can contribute much to reducing noise levels, particularly along roads and highways. Trees alone can help to attenuate noise levels, but the best results are obtained by combining earth berms and trees, with tall conifers and underbrush being the most effective.

In addition to reducing noise levels, trees can also reduce the effects of another major problem in urban areas, that of light pollution caused by direct light sources and reflection. This can be accomplished in three ways: (1) by keeping direct light off reflective surfaces, as occurs when a white concrete surface is shaded by trees; (2) by keeping reflections away from viewers, as is achieved when glare from reflective glass windows is shielded from viewers in residences, work places, cars, or on sidewalks; (3) by shielding viewers from direct light sources, as is accomplished by trees planted along roadways to prevent headlights, streetlights, or other bright lights from interfering with people's enjoyment of their residences or other activities.

While trees can help reduce the unpleasant side effects of traffic such as noise, air pollution, and glare, they can also contribute to the functional aspects of vehicular transportation. This can be achieved by using trees to clarify road patterns and highlighting the locations of intersections, and by using trees to screen the headlights of oncoming traffic. Generally, the aesthetic benefits of street trees can also be enjoyed from a moving vehicle, just as from a building or a sidewalk. Indeed, the sequential effect of passing through areas of street trees can do much to enhance the experience of vehicular travel.

The final functional benefit of street trees considered here is that of erosion control. The most important point in the erosion of soil by water is

when soil particles are dislodged by the impact of rain drops. The crown of a tree helps to prevent erosion by intercepting rain drops, a factor that is especially important in areas where the soil surface has been disturbed by construction activities. Tree roots also help control erosion by holding the soil mass together, reducing sheet and rill erosion, and mass failure (slumps). Leaves on the soil surface also reduce rain drop impact and can act as a sponge, therby reducing the amount of, and slowing the rate of, water runoff. This results in less water erosion in channels downstream, and a general improvement in water quality and stability of water flows. Wind erosion is also reduced by trees, because they cause a general decrease in wind speed near the soil surface.

The aesthetic benefits of street trees are numerous and complex, though rather less tangible than the foregoing functional benefits. Nonetheless, the asthetic benefits are equally important in terms of the contribution that street trees make to urban life. Street trees play a major role in the creation of, and the definition of, the distinctive urban spaces of communities. Street trees can create a sense of unity through the community, giving various districts the.appearance of being part of a common fabric. Trees can give streets, and other urban spaces, a visual structure or volume; they help to define spaces generally; and also they create, frame, or define views and vistas. Hard architectural lines and forms that can completely dominate urban settings can be softened bystreet trees, generally resulting in greater pleasantness and attractiveness for the community. Trees can help to contribute these quantities to the community for all the reasons already described, but also because of the unique inherent attributes of the trees themselves. The foliage of trees adds color, texture, variety and vividness to a community, and these vary through the seasons--from the first fresh flush of buds and flowers in spring, to the full rich green colors of leaves and fruits in autumn. And in winter, coniferous trees, of course, continue to add much needed color and form to the community, while deciduous trees, without their leaves, can display their elemental form-distinctive branching patterns, fruits, seeds and bark texture. There is also a secondary benefit of street trees: providing habitat for birds and squirrels. These creatures add a great deal to the interest and variety of urban life, and birds in particular do much to help control insects.

Finally, street trees make a great contribution to the overall attractiveness, image, and character of communities. In part as a result of the factors described above, but also because they provide a sense of growth and prosperity, for trees grow and change; and a sense of security and continuity, for trees are long-lived and stable. The street trees of a community become part of its history and character; they grow and prosper, as do the people of the community, and because the life span of many trees is longer than that of people, the trees provide a setting for socialization among a generation--a source of challenge for tree-climbing children--and a form of contact between generations--a shady spot where the old timers can tell stories about the people who planted the trees, and where people can reflect on the past and the future.

The most important concept though, is that the presence of street trees is an indication of the pride that people have taken in their community, and of the confidence they have in, and the commitment they have made to, the future.

All these contributions that street trees can make to the quality of urban life can culminate in economic net benefits for the community. These benefits are not liquid assets, to be sure, but they can nevertheless be of considerable long-term value. The general contribution of street trees to the attractiveness of the community can make it much more interesting to businesses looking for a community in which to locate, and also to potential employees, in terms of moving to, and remaining in, the community. Street trees can also do much to make commercial areas more appealing to shoppers, with benefits to the merchants.

Street trees can have other general benefits for the community for, as mentioned earlier, trees can reduce surges in storm water runoff. This can help reduce wear-and-tear on constructed and natural stormwater drainage systems. Minor, but useful, byproducts of street trees can include firewood for the community from waste wood (for example, pruned branches), and the leaves can serve as garden mulches.

Street trees can provide a direct economic benefit to owners of residential property. Residential lots with adjacent street trees have a higher property value than lots with none. Street trees can also lead to reduced heating costs by sheltering structures from the wind; however,care must be taken to prevent interference with solar energy gain for structures during the cooling and cold months.

Generally, the quantity and quality of all of these benefits will increase as street trees grow and mature. That is, as an investment street trees appreciate, rather than depreciate, in value. However, many of these benefits can be negligible in the case of a single tree, or a small number of trees. To fully realize the full potential and value of

street trees it is necessary to establish a well-organized, comprehensive and long-term street tree program.

GENERAL GROWTH CHARACTERISTICS OF TREES

In order to better understand street trees, a basic understanding of the anatomy and functions of a normal healthy tree is necessary, and general background information on this subject is presented in this section.

A tree is divided into three major parts: the trunk, the crown and the roots. Each of these structures is related to the other and each has specific functions to perform to maintain the growth process.

Trees are adapted to the environment in which they evolved, and their form, habit, branch structure, wood, bark, twigs, leaves, roots, flowers, fruit, and seed will reflect the conditions of the native habitat of the tree.

Branch and Crown Development

The trunk of a tree has several functions: structural support; conduction of water, food, and nutrients; and the storage of food materials. The crown of a tree also serves to support the leaves in such a manner that they may achieve maximum exposure to the sun to facilitate photosynthesis. This is accomplished by means of multiple branching of the tree trunk into limbs, branches, and twigs. The trunk and its subdivisions are the connecting links between the roots, where water and soil nutrients are absorbed, and the leaves, where food is manufactured.

Root Development

Normal healthy growth of trees and shrubs depends upon an interrelated balance of the functioning of all plant parts--leaves, branches, stem and roots. The roots of trees and shrubs serve several vital functions: (1) anchorage for the plant in the soil substrate, (2) absorption and uptake of water, oxygen and nutrients, (3) food storage, and (4) transportation for nutrient distribution.

Normal healthy growth of trees and shrubs depends upon an interrelated balance of the functioning of all plant parts--leaves, branches, stem and roots. The roots of trees and shrubs serve several vital functions: (1) anchorage for the plant in the soil substrate, (2) absorption and uptake of water, oxygen and nutrients, (3) food storage, and (4) transportation for nutrient distribution.

Many tree and shrub species develop a characteristic root form that is inherent, and is most recognizable only during early seedling growth. As the plant grows, its root system usually becomes greatly modified by environmental influences such as soil texture, moisture availability, and nutrition. These factors cause wide variation in the branching pattern, depth of soil penetration and lateral spread of roots, even within the same plant species. An understanding of the general structure and ecology of root systems can be helpful in the selection of the most appropriate species of street trees, in their subsequent planting, care and maintenance, and for their overall compatibility with the urban environment. Knowledge of the pattern of water and nutrient conduction from roots to leaves is also important in predicting the likely effects of fertilizer, insecticide and herbicide applications, and of the effects of mechanical injuries to the root system.

In general, at least 95 percent of all roots are within the top surface metre of soil. For many tree and shrub species, the first root formed is often a taproot or primary root that grows downward directly below the stem. Its depth into soil may vary from 1 to 2 metres and is limited by oxygen supply or some physical barrier. Secondary or lateral roots branch out from the central taproot and grow radially and horizontally through the soil. These in turn may branch and re-branch into tertiary roots. For some species, such as spruces, willows, and poplars, a taproot may not usually persist beyond the early stages of growth. In these species, the root system becomes more fibrous. Oak and pine are examples of trees with a predominantly taproot system. Almost all the recommended street trees in Alberta have fibrous root systems, but a few have taproot systems.

The number of main lateral roots growing out horizontally from the upper taproot region (root collar) at or near ground level may vary from 4 to 11 for most trees. The lateral roots usually have a zone of rapid taper within 1 to 2 metres from the tree trunk, beyond which they appear "rope-like": with little taper and often extend 15 to 20 metres on mature trees. They may range in diameter from over 30 cm at the root collar of mature trees, and

taper to less than 0.5 mm. These lateral roots are woody, often show annual growth rings, and tend to fan out both radially and horizontally within the top 20 - 30 cm below the soil surface. Such lateral roots are also "transport" roots and may encompass a circular area 4 to 7 times that projected by the tree crown. Some lateral roots, such as in poplars, may extend 1 to 2 times the height of the tree.

In most coniferous and deciduous species, numerous striker or "sinker" roots grow out from secondary roots, descending into the soil more or less at right angles with the main laterals. These mostly occur within 1 to 2 metres radius of the main stem. Their initial development may commence at a very early age, and depth of descent is influenced strongly by soil moisture conditons and physical obstacles. Sinker roots and the taproot often branch to form a second layer of lateral roots that grow radially and horizontally. The combined structure of taproot, laterals and sinkers form the basic architectural framework of root systems. However, a complex of smaller roots grows outward and predominantly upward from this basic framework, forming a matt of fine, short, non-woody root tips 1 - 2 mm long and 0.2 - 1 mm in diameter. These are termed "feeder roots" and are the primary site of water and mineral absorption. They may or may not have fine root hairs associated with them. Because of their delicate nature and close proximity to the soil surface they are constantly subjected to injury from such agents as soil nematodes, soil-inhabiting insects, compaction, surface drying, frost action, or surface-applied toxicants. In general, the surface layers of soil tend to have the highest concentration of available nutrients where most of the feeder roots are located.

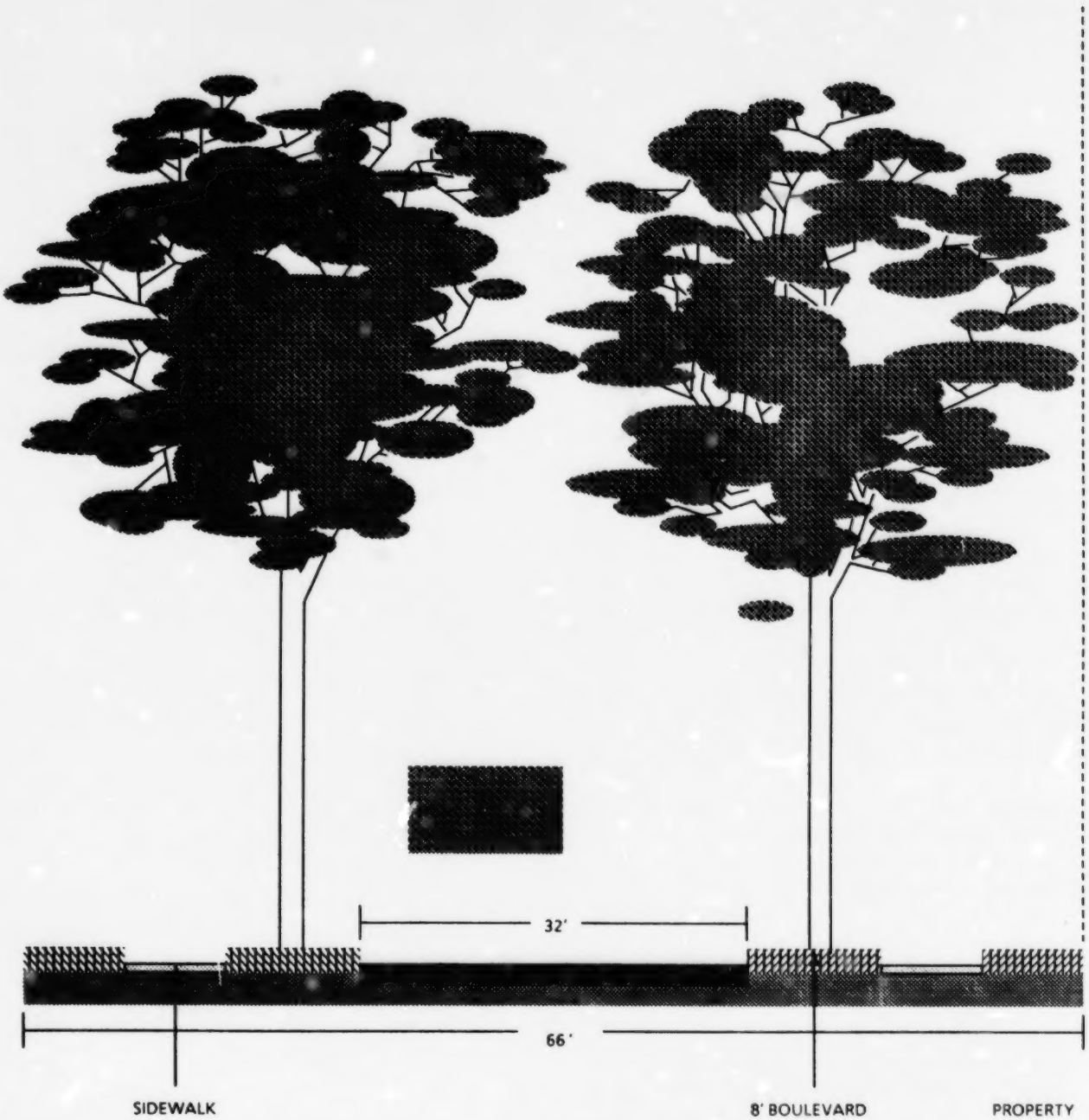
Soil conditions conducive to healthy root growth may have a high percentage (e.g., 50 percent) volume in pore space. This facilitates easy root penetration, oxygen availability, and allows water and soil nutrients to percolate freely. Most tree and shrub species grow best in light, deep, clay-loam soils in which root development is most profuse, whereas shallow wet soils tend to restrict root growth.

Root growth occurs largely in response to the temperature, moisture and physical characteristics of the soil. The roots of a tree do not all grow at the same time; some may be quiescent while others are growing. Many broadleaf and coniferous tree species have a period of peak root growth in the spring, followed by a reduction of growth during summer and another peak of growth activity in the fall. With the onset of winter and reduced soil temperatures, most roots become quiescent.

A large proportion of the root system occurs within the top few centimetres of soil, and additionally, many lateral roots often extend far beyond the perimeter of the tree crown. Consequently, fertilizers broadcast on the soil surface become immediately available to the tree roots. These characteristics serve as a cautionary warning when applying insecticides, herbicides and soil sterilants to the soil surface near trees and shrubs. Improper use of these chemicals can injure roots directly or the chemicals can be translocated up the tree and result in such phytotoxic effects as discolored leaves, bud and shoot kill, shoot curl, premature defoliation, and ultimately, tree death. Some broadleaf species such as poplars grow sprouts from the roots. Treatment of these with herbicides may kill the entire tree because of root translocation. Similarly, trees of some species growing adjacent to one another may develop intertree root grafts, and herbicides applied to kill one tree may graft to kill an adjacent untreated tree. Occasionally, diseases such as Dutch elm disease may spread from one tree through root grafts to infect another.

Various toxic chemicals from exhaust, deicing salt used on roadways, old crank case oil and high concentrations of detergents can also be toxic to trees and shrubs. For example, spruces show a high sensitivity to salt accumulations and should not be planted immediately adjacent to main roadway arteries maintained for heavy traffic flow where salt is regularly applied in the winter.

Soil compaction and limited oxygen availability are two important factors that restrain healthy root growth. Heavy or wet soils are most prone to compaction and considerable care should be taken to protect trees in such soils especially in park or other landscape areas of high pedestrian use, or where vehicles may have access.


32'
66'
SIDEWALK
8' BOULEVARD
PROPERTY

THE COMPONENTS OF A SUCCESSFUL STREET TREE PROGRAM

A street tree program could be considered to consist of four main stages: planning, design, implementation and routine maintenance. The purpose of this section is to describe the activities that should take place during each of these steps. The first two stages, planning and design, would preferably be carried out by professional staff or consultants, primarily landscape architects or horticulturists working in concert with municipal engineers. The last two stages, implementation and maintenance, could be carried out by trained municipal forces. More detailed and technical information is presented in these sections.

Planning

The planning stage consists mainly of basic policy development and other preliminary steps to lay the groundwork for a street tree program. A vital part of a street tree program described here is the creation of lines of communication that will enable municipal engineers and landscape architects to coordinate their planning activities, that is, the location of utilities and roads vis-a-vis the location of street trees. Other preliminary activities, such as developing public involvement, and generating background information, are also described in this section.

Public Involvement

Public awareness of and support for a street tree program is essential to its success. A major goal of such steps is to engender a sense of stewardship--a protective attitude--in citizens towards their street trees.

Public support and input can be motivated by newspaper notices, inserts in utility statements, posters, door-to-door surveys or other locally-effective measures. In order that discussion and exchange of viewpoints can occur, meetings with interested residents are useful. Presentations and open workshops that convey information about street tree programs would facilitate public discussion and awareness. The inclusion of service clubs and other organizations in a street tree program is a means to gain active community involvement (for example, tree planting by citizens, or fund raising).

Interdepartmental Cooperation

For the street tree program to be successful it is essential that all departments and agencies work together. In many municipalities, the responsibility for trees is divided among parks, planning, engineering, and public works departments. The mandates of these departments differ, as do their attitudes towards street trees. Without a clear statement of street tree policies and responsibilities from the political level, the program will suffer from lack of management. Street trees are a valuable asset to the community and they should not be left to chance orjeopardized by poor cooperation or communications.

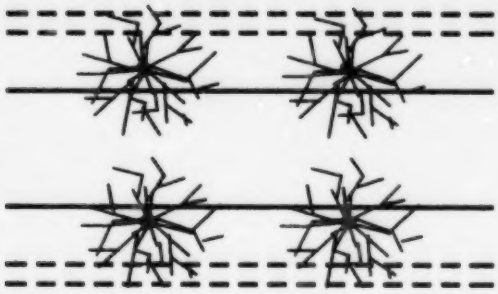
Coordination of Utility and Street Tree Planning

In order to receive the benefits of street trees, every attempt should be made in the planning and design of the infrastructure of new developments to coordinate the design of overhead and underground utilities, and streets and sidewalks, with a street tree planting plan. An integrated approach to urban planning should be used, with maximum coordination, at all stages, between municipal engineers and landscape architects.

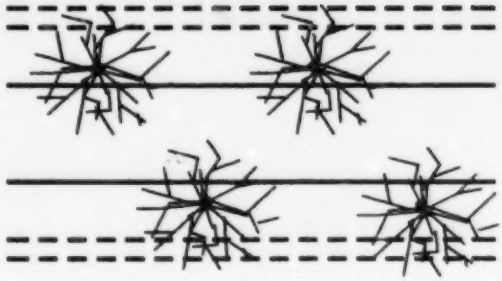
Utilities should be routed where they will not conflict with important plantings, and sewers and conduits should be of a root-proof design, or buried deep enough that root intrusion will not occur. Roads and sidewalks should be designed so that medians and boulevards are wide enough to accommodate the desired tree species at the mature size, and such that adequate room for tree root growth is provided. Trees are a major part of the ultimate image, value, and beauty of a development, and every effort should be made to facilitate the achievement of a high-quality urban environment by coordinating the planning, design, and construction of utilities in new developments with street tree planting plans. However, engineering constraints must be recognized when planting plans are prepared, and trees must also be selected which have crown and root growth habits which will not conflict with utilities, roads and sidewalks.

In older developments, where utilities, roads and sidewalks are already in place (and are likely to be of a less-advanced design), trees species must be selected, and located on-site, judiciously, in order to avoid conflicts. However, the ultimate benefits of trees must be kept in mind, and if at all possible, efforts should be made to upgrade or rebuild utilities, roads and sidewalks to accommodate tree plantings.

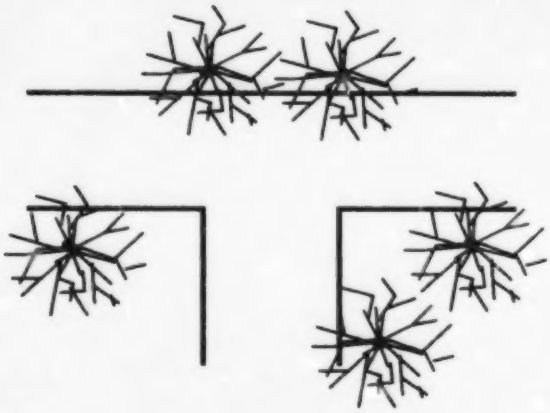
ADAPTING PLANTING TO SITE CONDITIONS



SPREADING SPECIES OR LARGE TREES MAY BE PLANTED OPPOSITE ON WIDE STREETS

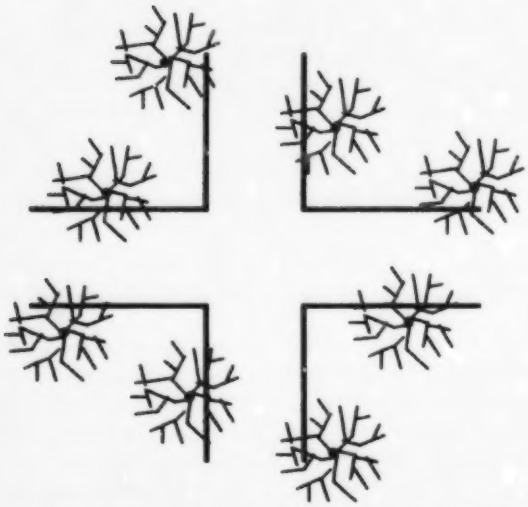


LARGE TREES OR TREES ON NARROW STREETS SHOULD BE STAGGERED

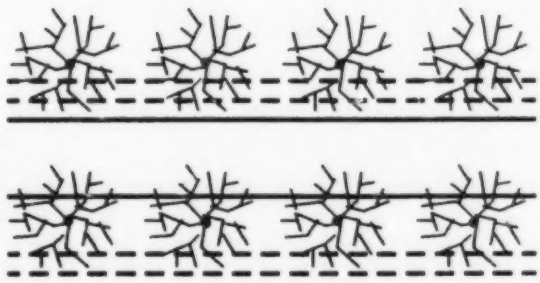


PLANTING TO INDICATE DEAD ENDS

PLANTING TO INDICATE SHARP CURVES



PROPER SETBACK FROM CORNER TO MAINTAIN CLEAR VISION



NARROW TERRACE MAY REQUIRE PLANTING INSIDE SIDEWALK; WIDE TERRACE PERMITS USE OF LARGER TREES

Inventories

Before deciding on the approach of a street tree program, the community should have an inventory of its trees. This survey should include a species list, numbers, sizes, condition, location, type of work required, missing trees, utility conflicts, and other items.

The street tree inventory should be complemented by an inventory of the community pattern. The community pattern inventory should address such items as: (1) the regional landscape in which the community is situated, in order to ascertain the general types of plantings most appropriate for the community; (2) significant landscape features for the community, including special places and spaces, existing important trees, major topographical features, and desirable and undesirable views; (3) land uses throughout the community; (4) streets, including identifying major and minor streets, street patterns, overhead and underground utilities, and planting strip widths. These two levels of inventories will assist the community in determining the type of street program necessary, and the structure of the organization needed to carry out the program.

Design

The design stage of a street tree program consists of two main areas of activity: development of a street tree planting plan, and development of utility plans. To achieve the maximum benefits of trees in the urban landscape these activities must be carried out with the greatest possible extent of coordination. The purpose of this section is twofold: (1) to describe the components of a street tree planting plan, while emphasizing the relationship of trees with utilities, and (2) to describe steps that can be taken in the design of utilities to ensure that minimal conflicts occur between trees and utilities.

Developing a Street Tree Planting Plan

A planting plan includes three principal items: (1) the development of an overall design concept, (2) the selection of appropriate tree species, and (3) placement of trees with respect to the site and each other. A key to developing the planting plan lies in the intent of the plan, or the desired effect of the planting on the urban environment. The element of time must also be considered in order to achieve the ultimate goal.

The challenge arises when the planner, parks administrator, or landscape architect must create a plan which is aesthetically pleasing, is functional, and accounts for the physical environment in which the trees must survive. Planting plans should be developed, in coordination, by qualified personnel from the parks department and the engineering department and preferably by a landscape architect as described earlier. Planting plans should be developed early in the planning of new developments, so that utility and street tree planning can be coordinated. The validity of all base information should also be checked against the actual site conditions (i.e., setbacks, location of utilities, etc.), in order to avoid problems at the time of plan implementation.

When developing planting plans in existing residential areas of a town or city, it is important to confer with the residents regarding the proposed improvements and the ownership of the planted trees, and to take advantage of the citizens' knowledge and input. If adjacent property owners support the planting program, then they are more likely to adopt a custodial attitude towards the trees.

General Design Concepts

When using trees in the urban landscape the designer must keep some basic principles of design in mind. These include: line, form, texture, color, repetition, variety, unity, vividness, balance, and emphasis. These aesthetic principles must be considered along with specific functions of the planting, such as visual control, physical barriers, climate control, noise attenuation, and erosion control.

Selection of Street Trees

Characteristics of the ideal street tree include:

1. A desirable amount of clearance at the base (i.e., 1.5 - 3.0 m).
2. A minimum amount of congestion in the crown.
3. Rapid growth in its immature stage.
4. Slow growth while full grown.
5. Minimal nuisance effects from leaf drop, seed drop, root development, breaking of branches, etc.
6. Total resistance to insect damage and disease attacks.
7. Total hardiness, drought resistance, and resistance to pollution from ozone and sulphur dioxide.
8. Need for a minimum amount of maintenance (pruning, fertilizing) while at the same time offering an optimum display of beauty.
9. Immunity from all the city abuses such as cars, vandals, dogs, etc.

Although no tree possesses all the desirable characteristics, through the use of good design and sound technical knowledge, planners can select trees suitable for the urban environment which will maximize the benefits to the community. Trees exhibit a number of common growth characteristics that should be considered in the selection of material. Such growth characteristics include: shape, height, spread, foliage color, density of crown, branch structure, twig color, bark, flowers, fruit or seed.

The final selection of a suitable species of boulevard tree will depend on the actual site with respect to:

1. intended use of area (i.e., residential, commercial, or industrial)
2. scale of street
3. available planting area
4. underground and aerial utilities
5. growth zone
6. available types of plant material.

Poorly selected street tree plantings may cause problems including:

1. large trees planted on narrow boulevards
2. large trees planted in areas with shallow boulevard setback
3. trees which produce messy seeds or fruits planted on residential boulevards
4. trees overhang low enough to obstruct traffic
5. trees too close to intersections, restricting vision
6. trees planted too close to utility lines, poles, driveways, walks or traffic signs.

Some guidelines relative to planting in the above locations should be considered. Generally, the larger the tree's ultimate size, the wider the planting strip required. The location should determine whether a small or large growing species should be used. Overhead wires will restrict upward development and narrow, confined locations will limit the spread of branches.

Where planting is done in the area between the sidewalk and property line, the building setback will often determine the species that can be used. In many instances too, as the trees grow, conflict may result between street trees and trees on private property.

Some types of trees are better suited to urban conditions than others, so plantings should consist of trees suitable for local requirements. Planting appropriate types of plant material reduces pruning requirements, pests and disease, leaf and fruit clean-up, branch breakage, disruption of utilities, sidewalk and pavement heaving, obscuring of traffic signs, or obstruction of drivers' vision. When selecting trees, itis best to use a variety of species because this reduces the threat of an insect infestation or diseasedevastating the entire tree population.

Some aspects of tree growth may create problems if the tree is inappropriately located, so it is essential to consider the characteristics of a particular location. For example, if the tree is to be located close to a heavily-used bicycle or pedestrian route, a wise selection would be a tree that does not drop its fruit readily, and has high branching characteristics to allow proper clearance beneath. A common maintenance concern is the need to prune branches frequently due to: trees interfering with each other, or overhanging branches obstructing traffic, walls, or signs creating visual hazards. Again, the selection of a tree with a branching habit suited to the urban location will alleviate potential problems.

Maintenance is a major concern with all municipalities, so wherever possible, trees that are asexually propagated should be selected in preference to seeding varieties. They provide uniformity in development, are easier and less costly to maintain, and as a rule are more attractive.

Location of Street Trees

The spacing of trees requires consideration at the planning stage. If the spacing is too close, overcrowding occurs, and increased competition between trees will result.

Street tree spacing is not only regulated by the species of tree, but also by the signs, driveways, crosswalks, intersections, and utilities which are located in the same area. Varieties of green ash, American elm, black ash, silver maple, and other large shade trees should be planted only where the planting strips are wide enough. Large trees should not be planted beneath overhead utilities; only those trees which will not interfere at mature height should be considered. Care should also be taken to avoid locating trees where they may interfere with solar access.

Utility Design and Street Trees

Underground Utilities

Trees and shrubs depend upon moisture and nutrients obtained from the soil and other sources, which are absorbed into the root sap system. Root growth tends to be opportunistic, extending within the soil substrate wherever the environment is favorable. Because of fluctuating water tables roots

tend to grow into new areas seeking moisture, including sewer and drainage lines, if these are not constructed to prevent roots from penetrating them.

In the urban environment, roots may follow sewers or conduits, sometimes for great distances, when these provide easy access to moisture. However, inadequate supplies of water are usually secondary to the major restraints to growing trees in urban areas: soil compaction and limited oxygen supply. Roots cannot grow where there is no oxygen, and where the soil is compacted and hard to penetrate, root development is severely restricted. The introduction of street trees to sites that lack sufficient space for proper root development may result in problems with sewer and other underground utility interference.

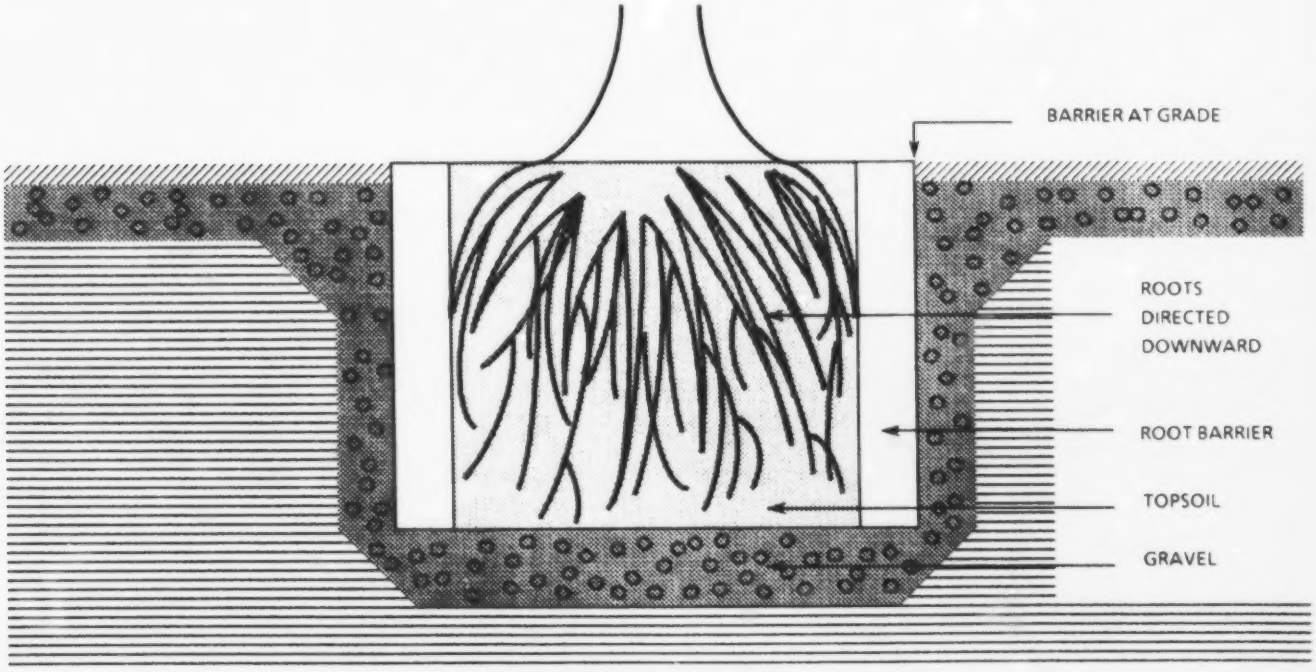
Sewer lines, because of their often loose construction (particularly older lines), allow fine roots to intrude at joints or into hairline cracks along the sewer pipe. Most intrusion occurs in house laterals where a sewer line is more shallow and the sewer may be poorly or unevenly constructed. Sewer pipes ranging in diameter from 20 - 30 cm are most often affected.

Trees planted along streets and on residential lawns are associated with the highest incidence of sewer-root problems, because of their location near house connections with street and easement sewers which have not been built to an adequate standard--a problem most common in older residential areas.

Tree species that are faster-growing have caused most sewer-root intrusions. In Alberta urban centres they have included poplars, willows, elms, Manitoba maple, birch, caragana and alder. Coniferous species do not appear to have contributed significantly to the problem.

Exfiltrated moisture from leaky sewer lines contributes to a moist, warm environment toward which tree roots may grow, and this facilitates direct contact between roots and sewer lines. Most roots invade the upper portion of sewer lines, apparently attracted more to the moisture vapor rather than to the liquid. Once inside the sewer pipe they grow rapidly in both length and mass, eventually clogging the line. Clogging results because of restricted liquid flow, and the gradual accumulation of grease, paper and other sewage particles.

Ground water infiltration or exfiltration is a common aspect of sewer system operation and maintenance in most urban centres. Roots and defective sewers are not compatible as roots may create a sewer maintenance problem. If water is found in or around sewers, roots will search it out, and in so doing, will penetrate the pipe, if it is not impermeable, and cause blockage. Roots, in conjunction with grease and sand, can contribute to clogged sewers, reducing flow characteristics. The remainder of this section is an examination of the design of storm and sanitary sewers, to identify approaches that can be used to avoid problems caused by tree roots.



ROOT CONTROL BARRIER
(TO PREVENT HEAVING OF PAVEMENT BY ROOTS)

Defective joints are the major points of root intrusion, as well as cracks and breaks in the pipe. The upper part of the pipe is where roots tend to be found in sanitary sewers, and along the pipe bottom in storm sewers. The importance of joints as the main points of root intrusion can almost certainly be attributed to older pipe joint design which used mortar and jute joints, or certain bituminous joint compounds. Defective workmanship and inspections, and inadequate replacement of sewers, have contributed to much of the root intrusion incidence.

Roots are a major problem in the sewer systems of older areas of the city, where the first pipes were laid during the early 1900's. As the main points of intrusion of roots into the sewer lines are in the joints, old clay tile sewer pipes are heavily intruded because joints are of cement mortar or cold mastic which do not tolerate much growth movement. Survey data indicate that current compression-type O-ring joints used in sewer pipes minimize infiltration and root intrusion. Problems of sewer blockage may not be as prevalent in the future as sewer systems in older residential areas are updated.

Future problems with root penetration of sewers can be prevented at the time of construction, through the process of "build-out". This involves the construction of sewer lines that provide water-tight and root-tight joints and pipe free from imperfections when installed and that will not crack, break or deteriorate during service. New construction materials are available for achieving this; pipe materials and joints are being manufactured that are generally capable of being installed to minimize root intrusion at joints.

Vitrified clay pipe is an overwhelming favorite among designers of sewer systems and accounts for about two-thirds of the total length of sewer in the U.S. today. If not fractured by unanticipated loads, this type of sewer pipe has a long record of service life because of the chemically inert characteristics of its material. Clay does not corrode, rust or deteriorate with age, and it resists attack from corrosive gases, wastes and soils, and consequently will not attract tree roots. In the past, when there was little concern about water infiltration and exfiltration, clay pipe was installed in shorter lengths, resulting in a greater number of joints. Jointing material in the past was frequently a cold mastic or cement mortar which could withstand little ground movement. Today, clay pipe is being fabricated in greater lengths, with greatly improved jointing systems.

All sewer joints should be installed in anticipation of some ground movement and to permit flexibility, in addition to being water tight and resistant to root intrusion. If a sewer is infiltration and exfiltration free, it will be root free.

Plastic pipe is relatively new to the waste water field. At this time most suppliers limit the size of the pipe offered to a diameter of 38 cm or less. Suppliers state that the plastic pipe will resist chemical and biological corrosion and also abrasion. Plastic pipe can be jointed by solvent cementing, heat fusion, or elastomeric seals (all of which are tight and root resistant).

Plastic pipe is somewhat flexible, accommodating some minor ground movement without fracture. This feature permits it to serve as an insertion liner in deteriorated sewers, restoring their usefulness without the inconvenience and expense of excavation and replacement. Most plastic pipe is made of polyvinyl chloride, some is made of polyethylene.

Currently available plastic pipe used in sewer line construction overcomes many of the earlier deficiencies that contributed to root intrusions. New plastic pipes of polyvinyl chloride or polyethylene materials are flexible, resist chemical and biological corrosion and are produced in longer lengths. The joints can also be sealed completely by solvent cementing, heat fusion or elastomeric seals.

Roads and Sidewalks

Roots will grow deeply into the soil if oxygen and water supplies are adequate. However, in impermeable soils, and under roads and sidewalks, roots will tend to grow parallel to the surface of the soil and along cracks in pavement for long distances.

A common problem in the urban environment is that spaces provided for root growth are often severely restrictive and surrounded by impermeable paving. Besides limited volume, the soil has low fertility, poor water content, and poor aeration. Constriction and poor soil result in stunted growth and possibly to eventual decline and death, and there is a greater likelihood that roots will damage structures in their search for sustenance.

As plants develop in soil surrounded by pavement, the roots tend to form primarily along pavement cracks, a demonstration of the need for adequate aeration and moisture, which may not be available beneath the pavement. As a result, the pavement may heave up or crack.

A method of root control which is effective in the

prevention of heaving is that of root pruning with the use of a deep root control barrier. A deep root barrier is located from the soil surface downwards into the soil after the roots have been pruned. It causes root re-growth to be directed downwards as roots are unable to penetrate the deep root control barrier.

Implementation (Planting)

The implementation stage of a street tree program is where the plans and designs are carried out, and the trees are planted. The purpose of this section is to describe the activities involved in successfully planting the trees, which include: (1) obtaining planting stock, (2) pruning for transplanting, (3) digging planting holes and placing trees in them, (4) fertilizing, (5) watering, and (6) staking, guying and wrapping.

Planting Stock

All planting stock should conform to CNTA standard specifications. Ideally street trees should not be bare-root, but should consist of balled or tree-spaded transplants. As long as the planting stock is viable, both balled and tree-spaded material are acceptable. When selecting balled and burlapped stock, a minimum ball depth of 30 cm is required, but the size of the root ball depends on the size of the tree, so the standard specifications should always be followed.

It is preferable that container grown stock for street trees be grown for the last two years of culture in a 20 litre container. In general, it is not recommended to move deciduous stock larger than five metres in height, or evergreens over three metres in height, especially in the case of planting stock with an unpruned root system. Larger trees can, of course, be moved also, but the complexity (and the cost) of moving larger trees is much greater.

In areas subject to vandalism, such as those near schools and playgrounds, larger planting stock should be installed. Smaller stock may not be able to withstand the abuse it may receive in these areas.

Pruning

Deciduous trees benefit from pruning immediately after transplanting. Reduction of the amount of leaf surface reduces evaporation, and will partially compensate for the loss of roots. As much as one-half to one-third of the leaf bearing branches can be removed in order to shape the crown. The goal is to achieve a strong well balanced and proportioned framework of branches originating from a central trunk. Nursery stock which has been previously root pruned does not require severe pruning after transplanting, but may require some corrective pruning.

The following method is recommended:

- At planting time remove broken, interfering, or diseased branches.
- Cut off dead branches flush to within 3 mm of live material.
- Remove broken and split branches flush to next branch or bud.
- Remove all suckers from the base, trunk and inside crown of tree.

Planting Methods

Planting Holes

Planting holes should be dug prior to moving the planting stock to the planting site. Holes may be dug mechanically by using a tractor driven auger or other equipment. Reliable measurements of the size of the root system (spread and depth) should be taken in order to determine the size of the planting hole. A minimum of 10 cm extra in all directions should be provided when digging the holes.

As street trees are often planted in paved areas of urban developments, special care is required in the preparation of planting holes where the trees are to be planted in a totally paved over area. Depending on the size of the tree, approximately a 1.2 m x 1.2 m area should be cut out of the pavement, and a 1.2 m deep hole dug. The bottom 30 cm of the hole should be filled with coarse gravel (4 cm size). The tree should be planted in fertile sandy loam and a root barrier is recommended. Part of the 1.2 m x 1.2 m planting hole surface may then be repaved using apermeable paving material or, preferably, left open using a tree grate to cover the soil surface. The use of tree grates is recommended to prevent the compaction of soil around the roots of the tree.

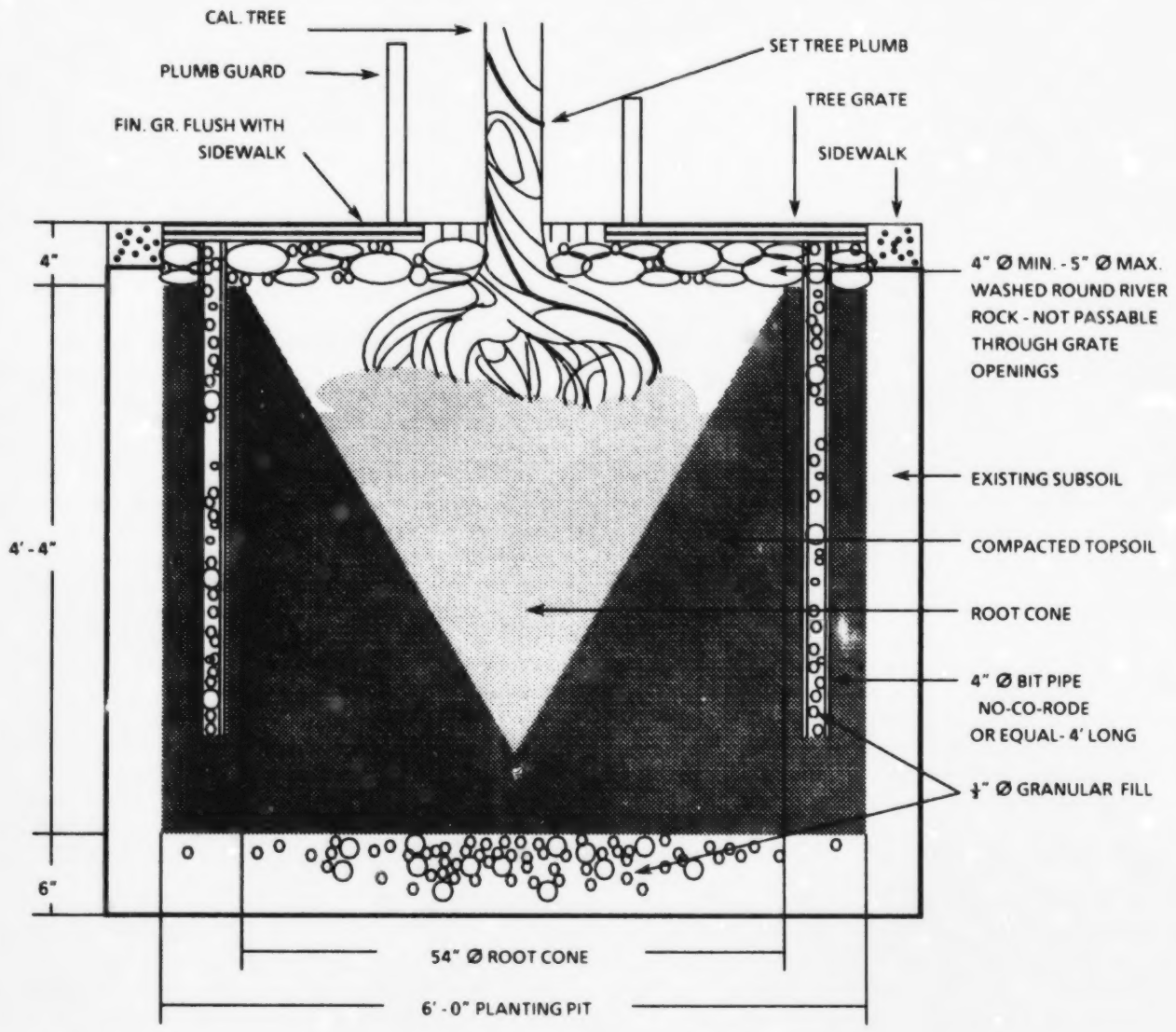
Fertilization

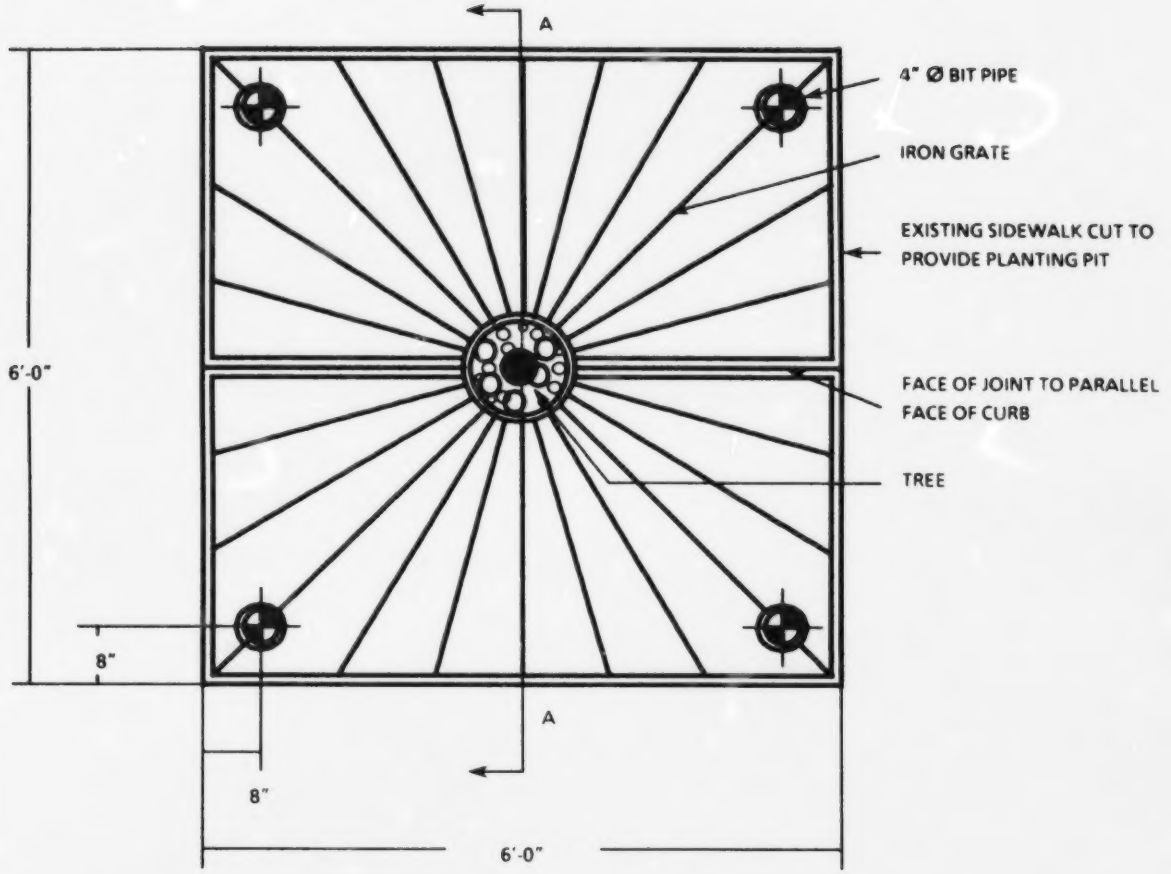
At the time of planting fertilizer should be placed around the root ball of the tree. This fertilizer should be a slow-release initial-starter type (for example, 10-52-10), and the main purpose of its use is to promote root growth. Specific fertilizer recommendations for a given setting should be made by qualified personnel.

Watering

For easy penetration of water to the roots of the

SECTION "A" TREE GRATE AND PLANTING DETAIL





TREE GRATE AND PLANTING DETAIL

newly transplanted tree, forming a ridge of soil immediately around the planting hole is recommended. The formed basin should be filled with water directly after the tree is planted and should be repaired as required before each watering. Watering should be repeated twice during the first week. From then on, the following guide as to the minimum amount of water required every week should be followed through the first growing season. These amounts should be adjusted to reflect climatic conditions in different areas of the province. Watering should be carried out by qualified personnel

TREE CALIPER	LITRES OF WATER
2.5 cm	67.5
5.0 cm	135.0
7.5 cm	202.5
10.0 cm	270.0
12.5 cm	337.5
15.0 cm	405.0
17.5 cm	472.5
20.0 cm	540.0

Staking, Guying, and Wrapping

Newly planted street trees need to be secured into place immediately after planting. Trees under 7.5 cm cal. should be staked, and larger trees should be guyed. Stakes should be located 5 cm outside the edge of the root ball on the street side of the tree. A second stake is recommended for 4 m cal. or greater with heights exceeding 1.5 m. The tie wire around the tree should slip through rubber tubing in order to protect the tree while allowing for growth. All wires should be tightened to eliminate slack.

Guy wires should be anchored in the ground with steel pins at a distance of 1/2 to 2/3 the height of the tree. These should be inserted into the ground at a 45 degree angle, all three anchors being equidistant from the tree. The wires should extend from the anchors to the tree and back, with rubber tubing on the wire around the tree stem. After all three wires are installed, they should be tightened until snug. Bright plastic ribbon should be tied onto each wire for visibility, and should be maintained as long as the wire is in place.

The trunk of transplanted deciduous trees should be wrapped with burlap, specially-prepared crepe paper, or some other material in order to prevent sunscald and drying of the bark. This also helps to reduce the possibility of borer infestation. The covering should be securely fastened with cord and left for a couple of years. Where tree trunks might be damaged by vehicles, vandalism, or by bicycles being chained to them, the installation of metal collars on a permanent basis should be considered.

Routine Maintenance

The maintenance stage of a street tree program is the longest activity, in that it continues for the life of the tree. This section describes three main aspects of the maintenance stage: First there is a discussion of general maintenance considerations, particularly the vital question of who will have responsibility for maintenance. Secondly, the topic of life cycle costing is addressed; that is, steps that must be taken to ensure a street tree population that is stable over the long term, by being renewed at appropriate intervals. This aspect of maintenance overlaps with the planning, design and implementation stages. Finally, information is presented concerning specific maintenance tasks that must be carried out. This information is detailed and technical because it is expected that municipal crews may carry out much of this work. The topic of sewer maintenance, in terms of root intrusion problems, is presented here, in order to describe methods that can be used to deal with root problems once they have occurred.

However, it should be emphasized again that the best solution to root intrusion is to ensure that sewer design and tree plantings are initially carried out to prevent problems from developing.

General Considerations

A systematic approach to street tree management is required to ensure that the many facets of tree maintenance are addressed. Tree maintenance programs available to a city or town can be either "in-house", private contract, provincial or utility company programs or a combination thereof. One very important step that must be taken is for community leaders and managers to agree upon, and to clearly identify, the maintenance policies and responsibilities. The maintenance program should ensure that the proper weekly, bi-weekly, or monthly duties be carried out as necessary. The need for qualified staff to implement any type of maintenance program is essential to its success. There are no rigid rules concerning who should have the responsibility and authority for doing the maintenance work on city property, but a decision must be made to clearly delegate this responsibility.

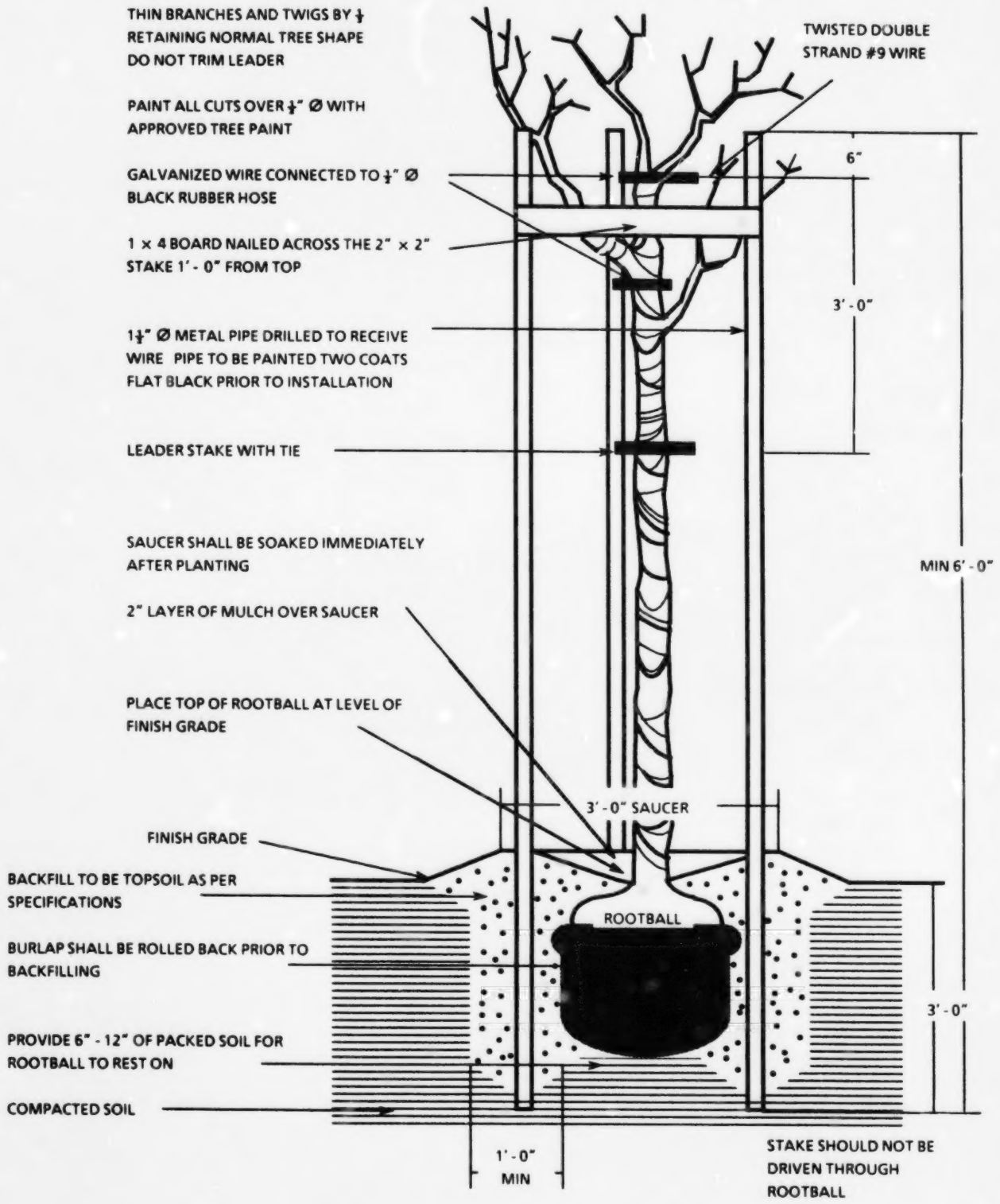
An "in-house" operation gives full control of what and how maintenance is carried out. It provides for instant response to problems and emergency work, continuity in maintenance, standard work, and records for claims. The inherent disadvantage lies in the possible shortage of funds to perform year round work, and finding and retaining skilled workers. One option that could be considered would be for a number of communities to share the cost of tree maintenance equipment and crews.

A contractual maintenance operation eliminates the need for training staff and purchasing equipment. It also eliminates the responsibility of employing staff and using equipment during the off-season or during inclement weather. Care should be taken to ascertain that the contractor's experience and reputation are adequate.

Provincial or utility company services usually cost a municipality less, however, the work is quite often carried out by unqualified staff and is usually done to benefit the limited objectives of the particular agency (for example, line or right-of-way). This type of maintenance is usually not carried out to encourage good tree development, but will be carried out in any event, to meet standards of the agency, unless the community takes the initiative in ensuring the work conforms to its standards.

No amount of maintenance will correct problems related to the poor selection and placement of

PLANTING AND STAKING DETAIL SMALL TREES 2½" CAL. AND SMALLER


THIN BRANCHES AND TWIGS BY ⅓ RETAINING NORMAL TREE SHAPE DO NOT TRIM LEADER
PAINT ALL CUTS OVER ¼" Ø WITH APPROVED TREE PAINT
GALVANIZED WIRE CONNECTED TO ¼" Ø BLACK RUBBER HOSE
1 x 4 BOARD NAILED ACROSS THE 2" x 2" STAKE 1' - 0" FROM TOP
1¼" Ø METAL PIPE DRILLED TO RECEIVE WIRE PIPE TO BE PAINTED TWO COATS FLAT BLACK PRIOR TO INSTALLATION
LEADER STAKE WITH TIE
SAUCER SHALL BE SOAKED IMMEDIATELY AFTER PLANTING
2" LAYER OF MULCH OVER SAUCER
PLACE TOP OF ROOTBALL AT LEVEL OF FINISH GRADE
FINISH GRADE
BACKFILL TO BE TOPSOIL AS PER SPECIFICATIONS
BURLAP SHALL BE ROLLED BACK PRIOR TO BACKFILLING
PROVIDE 6" - 12" OF PACKED SOIL FOR ROOTBALL TO REST ON
COMPACTED SOIL
TWISTED DOUBLE STRAND #9 WIRE
6"
3' - 0"
MIN 6' - 0"
3' - 0" SAUCER
ROOTBALL
3' - 0"
1' - 0" MIN
STAKE SHOULD NOT BE DRIVEN THROUGH ROOTBALL

trees. While frequent, and often expensive, steps may be taken to correct problems caused by a poorly placed tree, it may have to be removed.

Life Cycle Costing

The street tree program should also be prepared to systematically handle work over the long term, meeting priorities for the removal and replanting of declining and otherwise undesirable trees in order to sustain the tree population. Dying trees must be replaced to maintain the aesthetics of an area, and to restore the monetary value that the streetscape has developed over the years. In addition, a replacement policy must be implemented in order to ensure that the trees are of varying ages, so that a succesion of growth will maintain the character of the streetscape.

Specific Tasks

Pruning

This section contains a number of guidelines that should be considered in carrying out routine pruning operations. In general, major pruning should be done during the dormant season but broken or diseased branches should be removed as soon as the condition is noted.

- Along roadways and walks, remove lower limbs to a height of 3.5 m using a drop cut.
- Remove all diseased branches at least 30 cm below disease, to the next healthy branch.
- Sterilize (formaldehyde or bleach) pruning tools to prevent spread of disease.
- Treat all wounds 25 mm in diameter or more with tree dressing applied properly and neatly.
- Considering growth habit of tree species, remove or shorten side branches to balance the outline of the crown.
- Correct growth direction by pruning branches back to a lateral branch growing in the desired direction.
- Remove or shorten branches growing over buildings and other structures.
- Always cut a branch back to a side limb that is no less than one-third its diameter.

In general, evergreens should not be pruned; however, if corrective pruning is required, the pruning period should occur between April 15 to May 15. Shade trees (except birch and maple) should be pruned while dormant (October 15 to April 15). Birch and maple should be pruned between June 15 and July 15, as these trees will bleed heavily early in the spring and in the fall. If fruit trees are to be used as street trees, they should only be pruned between March 15 and April 15.

Another type of pruning is utility line clearance, which involves the pruning of parts of the trees which conflict with power lines, other aerial utilities, street lighting standards and traffic lights. This type of pruning should be performed with as much care and sensitivity as maintenance pruning. Having discussions and making voluntary agreements with other agencies should prove fairly effective in reducing the severity of pruning damage. The municipality should draft utility line clearance guidelines for use by utility company clearing crews. These guidelines should establish proper pruning standards and techniques, a permit system and inspection procedures. Another possibility that would enable greater quality control for the overall pruning of the trees would be to have the municipality perform line clearance for the utility companies.

Control of Suckering

Suckering is a natural growth occurrence commonly associated with such species as poplar, willow, and Manitoba maple. It is a natural means of asexual propagation which occurs at nodes along the roots of plants. It may occur naturally, or as a result of injury (i.e., roots on the surface of the ground cut by a lawn mower, or the result of a tree being severely pruned back or cut down).

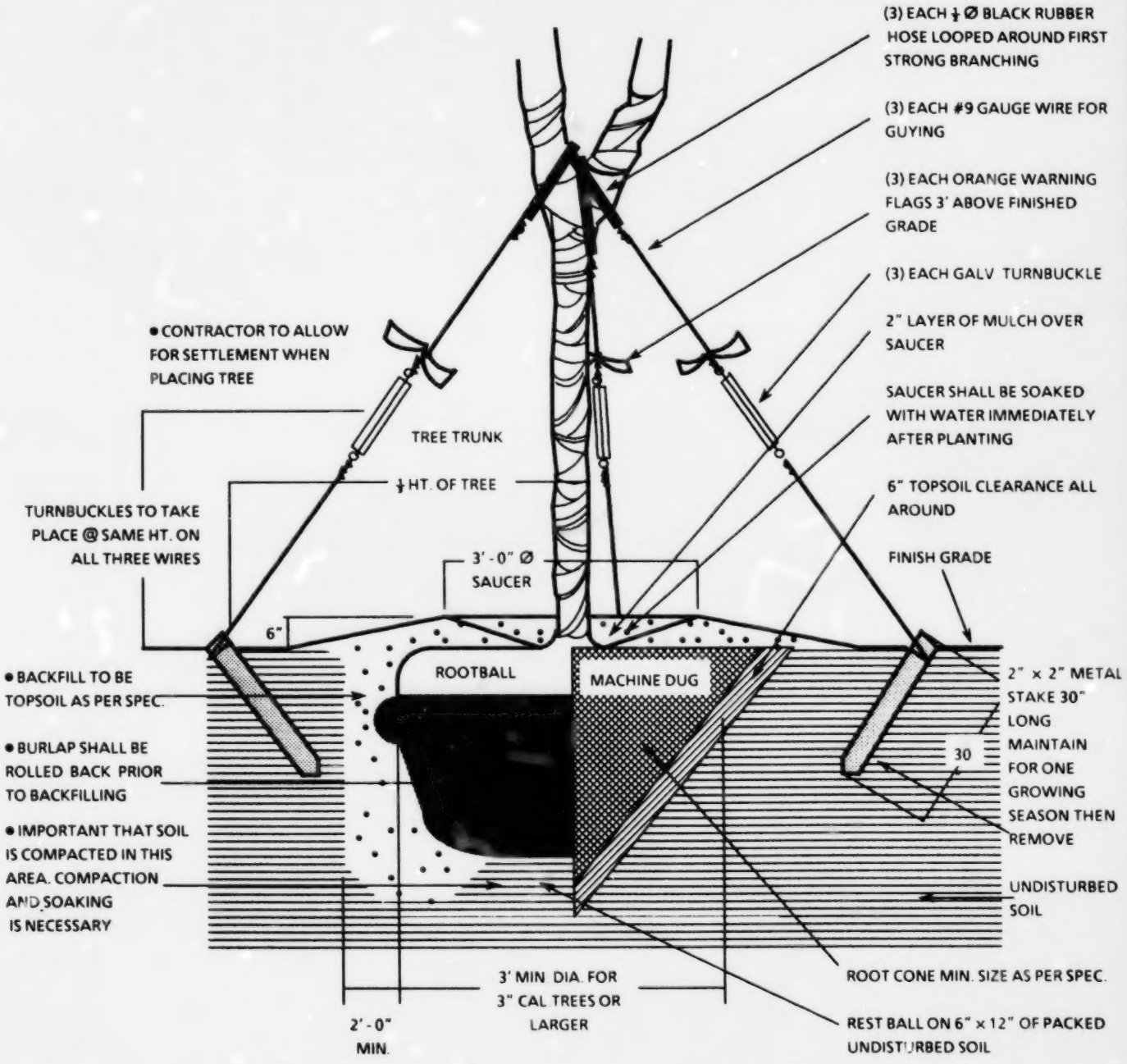
The removal of newly suckered growth is maintenance intensive, and may be done manually or with the use of a herbicide. Only qualified personnel should work with herbicides. Caution should also be exercised when using a herbicide, because suckers are connected to the root system of the entire plant. Suckers can be removed any time during the year.

Watering

Watering should be carried out as required throughout the growing season by qualified personnel. The amount and timing of watering will vary according to the tree species, its age, the season, soils, location, and the region in the province.

Maintenance may be carried out during the watering operation (i.e., removal of weeds, adjustments to staking or guying, removal of broken branches, and wound repair). All damage to trees should be reported.

PLANTING DETAIL FOR DECIDUOUS AND CONIFERS 3" CALIPER AND LARGER


(3) EACH ¼ Ø BLACK RUBBER HOSE LOOPED AROUND FIRST STRONG BRANCHING
(3) EACH #9 GAUGE WIRE FOR GUYING
(3) EACH ORANGE WARNING FLAGS 3' ABOVE FINISHED GRADE
(3) EACH GALV TURNBUCKLE
2" LAYER OF MULCH OVER SAUCER
SAUCER SHALL BE SOAKED WITH WATER IMMEDIATELY AFTER PLANTING
6" TOPSOIL CLEARANCE ALL AROUND
FINISH GRADE
• CONTRACTOR TO ALLOW FOR SETTLEMENT WHEN PLACING TREE
TREE TRUNK
¼ HT. OF TREE
TURNBUCKLES TO TAKE PLACE @ SAME HT. ON ALL THREE WIRES
3'-0" Ø SAUCER
6"
ROOTBALL
MACHINE DUG
• BACKFILL TO BE TOPSOIL AS PER SPEC.
• BURLAP SHALL BE ROLLED BACK PRIOR TO BACKFILLING
• IMPORTANT THAT SOIL IS COMPACTED IN THIS AREA. COMPACTION AND SOAKING IS NECESSARY
2" x 2" METAL STAKE 30" LONG MAINTAIN FOR ONE GROWING SEASON THEN REMOVE
30
UNDISTURBED SOIL
ROOT CONE MIN. SIZE AS PER SPEC.
3' MIN. DIA. FOR 3" CAL TREES OR LARGER
2'-0" MIN.
REST BALL ON 6" x 12" OF PACKED UNDISTURBED SOIL

Fertilizing

Once trees are established, fertilizer should be applied periodically, as required, based on selective soils tests and recommendations by qualified personnel.

One approach to fertilization is to apply a dry fertilizer (for example, 10-6-4) at the rate of 1.4 kg per 2.4 cm caliper of tree. Fertilizer holes should be drilled 30 to 50 cm in depth (5 cm diameter) and located 60 cm apart in circular rings beneath the tree (starting one-third of the distance from the trunk to the dripline). 100 grams of fertilizer should be applied per hole. Alternatively, fertilizer can be dissolved in water and applied with a water truck, as long as an adequate application rate is used.

As an alternative, tree spikes (16-8-8) may be used at the rate of one spike per 2.5 cm caliper of tree.

Wound Treatments

Wounds caused by pruning or bark injury should be treated as soon as possible in order to prevent insect infestation and disease. All large wounds should be smoothed over and thenshaped into a pointed ellipse in order to aid in rapid callus formation. Following this the wound should be painted with shellac, and once dry, a wound dressing applied over the entire exposed surface.

Wound dressing helps to protect exposed surfaces and to facilitate healing. They are best applied when the wound is dry. An ideal wound dressing would: disinfect the area, prevent entry of fungi and parasitic organisms, and stimulate callus formation. It would be easily applied, sufficiently porous to allow evaporation of excess moisture, and would not crack after drying. Unfortunately, no single wound dressing meets these qualifications although these are most commonly utilized: orange shellac, asphaltum paints, creosote paints, grafting waxes, lanolin paints, and commercial tree paints.

Insect and Disease Control

Insects can cause several problems detrimental to the healthy growth of trees. Depending upon the type of insect and the stage in its life cycle, damage may affect the leaves, buds, bark, trunk or roots. Insects commonly damaging trees include sawflies, moths, beetles, scales, mealybugs, spider mites and borers.

Disease caused by viruses, bacteria and fungi, also occur on a wide variety of street trees. A diseased tree usually develops one of three groups of symptoms: tissue death, dwarfing or undevelopment, or overgrowth. The more common diseases include fireblight, crown gall, powdery mildews and cankers.

Diseased or infested trees should be diagnosed by a knowledgeable person, and control measures taken as quickly as possible. Effective control may include spraying (but only by qualified personnel), pruning infected areas, or possibly removing infested trees to prevent the spread of disease or infestation.

The best method of preventing disease or infestation may be achieved by:

1. Purchasing stock from a reputable nursery.
2. Verifying the health and condition of plant material before acceptingit.
3. Taking precautionary measures such as fertilization, watering, and soil improvement.
4. Avoiding stressful conditions (i.e., drought, excessive moisture,lack of nutrients, chemical/mechanical injury).
5. Performing proper maintenance including watering, pruning, reparationof damage, transplanting during proper times of the year.
6. Monitoring the condition of the trees regularly.Prevention of Vandalism

A major area of concern regarding the trunks and branches of street trees is vandalism. Prevention of vandalism is difficult, so a good maintenance program is necessary to ensure that any injuries are treated promptly to reduce the chances of disease or insect infestation. Where vandalism is a threat, trees should be protected by metal collars. Vandalism may be reduced through a public involvement program, as described earler, which would lead to greater awareness and appreciation of street trees.

Prevention of Maintenance Damage

One aspect of tree damage which can be prevented by maintenance departments is the negligent use of maintenance equipment, which can be as destructive in the damage of trees as automobiles and vandals. When the danger of such mechanical injury is constant, trees should be protected by tree guards. Also, if no turf is planted close to the trunk, there is a reduced chance of damage. Grass trimmers can be a particular problem in causing damage to the trunk at the ground level, where it is very vulnerable to insect invasion.

When construction work, whether public or private, must take place in the vicinity of street trees, steps

should be taken to ensure that no damage is inflicted on trees or their roots, and that root areas are not compacted.

Utility Maintenance

This section describes methods that can be used to deal with roots that have intruded into sewer lines and are creating problems by blocking or damaging the lines.

Root growth may be year-round but the general experience is that roots intrude into sewer pipes most heavily in the fall and in the spring. There are three main approaches to root removal: block-out, clean-out, and snuff-out. The first approach, block-out, is one that can be taken to prevent root intrusions into existing sewers. The last two are approachesthat can be taken after root intrusion has occurred.

Block-out

Block-out involves the sealing or closure of defects in the pipe. These block-out practices include use of chemical sealing, grouting or repair of defects, insertion of pipe or tube structures, and actual replacement of section of sewer lines (which could then be classified as "built-out").

Clean-out

Roots in sewers are often removed physically by such devices as "snaking" or cutting tools. This method provides only temporary control since the roots regrow and may even rebranch more profusely. In addition, cleaning does not remove all roots within the sewer.

Snuff-out

Snuff-out involves the use of inhibiting chemicals which attack the finer root filaments causing them to disintegrate. These chemicals are herbicidal and must therefore be used with extreme caution. Chemical treatment varies from the simple to the sophisticated. Periodic dumping of dry chemicals into manholes upstream of heavily infested sewers and the solution of this material in the sewage flow during indeterminate periods is a simple but ineffective procedure.

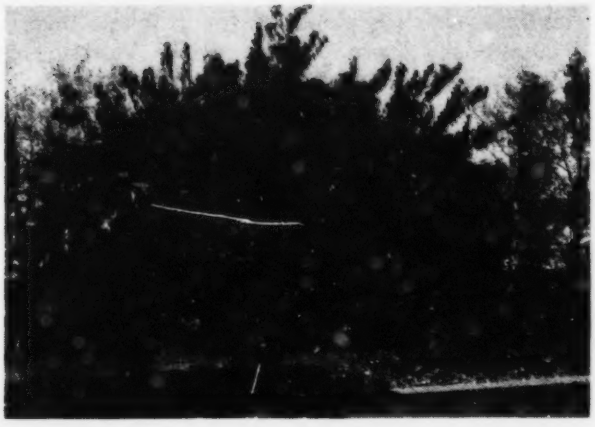
One of the most commonly-used chemicals is copper sulfate, which is placed in the manhole invert or occasionally down a toilet bowl. However, the copper sulfate dissolves in the flowing wastewater and roots entering the sewer from the top can still form the familiar and troublesome root curtain and ultimately block the sewer without coming into contact with the treated wastewater.

Soaking and foaming have been utilized in root control work, primarily with two herbicidal chemicals: Methan, or sodium methyldithio-carbonate (24.5 percent), and dichlobenil, known as 2.6 dichlorobenzonitrite (1.77 percent). The herbicide also contains inert ingredients including grease emulsifiers, nonionic surfactants, and foaming agents. When this chemical combination, known as Vaporooter, is applied in the sewer, the roots absorb the inhibitor and die away.

Moreover, inorganic colloids and soil in the sewer joints and pipe breaks absorb the inhibitor, permitting it to remain effective for 2 to 4 years. In large sewer mains, this root inhibitor can be sprayed onto the upper portion of the sewer above the wastewater flow. Metham and dichlobenil are also being incorporated in commercially available sewer application materials and in the major sewer sealants.

In Canada, some research has been done to investigate the efficiency of different herbicides to control root growth. Picloram, a wide spectrum herbicide, was found to be the most effective compound for root control under laboratory conditions. This compound is relatively persistent and residual phytotoxic effects have been observed several years after a single application. For this reason, the use of Picloram for tree root control should be monitored closely when used in the urban environment.

Root intrusion is just one of many sewer maintenance problems, but it is by no means the only cause of system malfunctions. A complete sewer maintenance program is needed based on the principles of preventive servicing to avoid drainage functions from being affected.



Ginnalian maple (*Acer ginnala*)

Ohio buckeye in centre (*Aesculus glabra*)

Russian olive (*Eleagnus angustifolia*)

Black ash (*Fraxinus nigra*)

Crabapple (*Malus* sp.)

APPENDIX A

Street Tree Species for Alberta

The following trees are suitable for urban plantings. Some of them are better suited to boulevard plantings than others.

The height and spread are those which can be reached under good growing conditions in a good area. In less than optimum conditions heights and spreads may be reduced.

The root spread is based on the height of the tree, the number being the multiplier of the height. Again these figures are only guidelines, as much depends upon the permeability, moisture content, nutrient status and the type of the soil.

Zone refers to the Canadian Plant Hardiness rating, which is determined by such factors as minimum winter temperature, amount of precipitation, wind conditions and average length of frost-free period. The zone given is the coldest area for a particular plant is only a guide and plants listed may well thrive in a colder zone. (See Appendix for Hardiness Zones in Alberta.)

SMALL TREES

GINNALIAN MAPLE

Acer ginnala

Height to 5 m
Spread to 5 m
Root Spread - 3.4 h
Growth Rate - medium
Zone - 2b to 9
Chinook Hardy

One of the most reliable red fall-colored small trees. Cannot stand alkaline soil. If pruned in winter, will bleed in early spring.

OHIO BUCKEYE

Aesculus glabra

Height to 8 m
Spread to 8 m
Root Spread - 2.0 h
Growth Rate - slow
Zone - 2b to 9
Chinook Hardy

A low headed tree with an irregular branching habit. Colors up well most falls. Often confused with the European Horse Chestnut, which is very rare. Tap rooted and difficult to transplant. The fruit is large and can be a nuisance.

RUSSIAN OLIVE

Elaeagnus angustifolia

Height to 10 m
Spread to 10 m
Root Spread - 3.0 h
Growth Rate - medium
Zone - 2b to 9
Chinook Hardy

A short lived small tree with attractive grey foliage. The leaves tend to be retained through the winter. The wood is weak and is subject to frost damage allowing secondary infections.

BLACK ASH

Fraxinus nigra

Height to 8 m
Spread to 4 m
Root Spread - 2.4 h
Growth Rate - medium
Zone - 2b to 9
Chinook Hardy

This tree, with an upright oval head, has smooth grey bark when young. Branching habit is good and the only serious problem is the seed on female trees. Seedless male selections are available including "Fallgold". Susceptible to the Ash Flower gall mite.

FLOWERING CRABAPPLES

Malus sp.

Height to 5 m
Spread to 5 m
Root Spread - 3.5 h deep
Growth Rate - medium
Zone - 2 to 9
Chinook Hardy (selected varieties)

A variable group of small flowering trees. The Pyramidal Manchurian crabapple is only about 2 m wide but can be 7 m tall, and it is susceptible to fireblight (as is Royalty). There are many selections available from white flowered through dark red flowers with red foliage. Fruit also varies in size from less than 1 cm to over 5 cm. Some remain on the tree and are eaten by birds while others fall and rot on the ground.

MAY DAY TREE

Prunus padus commutata

Height to 10 m
Spread to 10 m
Root Spread - 4 h

Green ash street planting (*Fraxinus pennsylvanica*)

Green ash (*Fraxinus pennsylvanica*)

Green ash as a street planting

Manchurian ash (*Fraxinus mandshurica*)

White ash (*Fraxinus americana*)

White spruce (*Picea glauca*)

Colorado blue spruce (*Picea pungens*)

Scots pine (*Pinus sylvestris*)

Ponderosa pine (*Pinus ponderosa*)

Tower poplar (*Populus* x *canescens* '*Tower*')

Pyramidal aspen (*Populus* sp.)

Larch (*Larix* sp.)

Northwest poplar (x *Populus*)

Bur oak (*Quercus macrocarpa*)

Growth Rate - fast
Zone - 3
Chinook Hardy

An outstanding spring flowering, low headed tree with grey, smooth bark. Also known as the European Bird Cherry. Suckers can be a problem on this tree and aphids may be nuisance.

SCHUBERT CHOKECHERRY

Prunus virginiana melancocarpa'Schubert'

Height to 5 m
Spread to 3 m
Root Spread - 4 h
Growth Rate - fast
Zone - 2b
Chinook Hardy

A small tree with white flowers and typical chokecherry fruit. The new growth is green but the leaves change to deep purple when fully expanded. This plant suckers heavily if on its own roots so is usually grafted onto May Day.

USSURIAN PEAR

Pyrus ussuriensis

Height to 8 m
Spread to 5 m
Root Spread - 4 h
Growth Rate - medium
Zone - 3b

A small neat tree, with spines and one of the first to flower in the spring. The large white flowers come out before the leaves and are followed by inedible fruit 5 cm in diameter. Rotting fruit can be a problem on lawns and the sidewalk in fall. Borderline hardiness in most areas.

MOUNTAIN ASH

Sorbus sp.

Height to 8 m
Spread to 5 m
Root Spread - 4 h
Growth Rate - medium
Zone - 3 to 9
Chinook Hardy

Small trees with good dark green foliage, large clusters of white blooms and clusters of red berries in the fall. Most have some red in the fall coloration. The bark is usually smooth varying in color from yellow-brown to brown. This family is sensitive to fireblight and also susceptible to damage from road salts.

MEDIUM TREES

MANITOBA MAPLE

Acer negundo

Height to 10 m
Spread to 10 m
Root Spread - 2.6 h
Growth Rate - fast
Zone - 2 to 9
Chinook Hardy

Although this tree will tolerate severe dry, polluted or windy conditions the wood is weak and easily broken by strong winds or heavy wet snow. Can bleed in spring if wounded and is host to the box elder bug and aphids. Burls can develop on the trunk of older trees giving character. 'Baron' is a very new seedless selection from Morden.

BIRCH FAMILY

Betula species

Height: 15 to 20 m
Spread: 10 to 15 m
Root Spread - 3.0 h shallow
Growth Rate - fast
Zone - 2 to 9

Chinook Hardy

Usually fairly short lived with shallow roots. Generally do well on moist soils but are intolerant of dry situations and are sensitive to salt.

MANCHURIAN ASH

Fraxinus mandshurica

Height to 15 m
Spread to 10 m
Root Spread - 2.4 h
Growth Rate - medium
Zone - 2b to 9
Chinook Hardy

The manchurian ash has a globe shaped head and has a coarser texture than the other ashes. Since most of the trees are grafted, only males without seed are available. This is a good clean tree, with very few problems. 'Mancana' is a newly named selection from Morden.

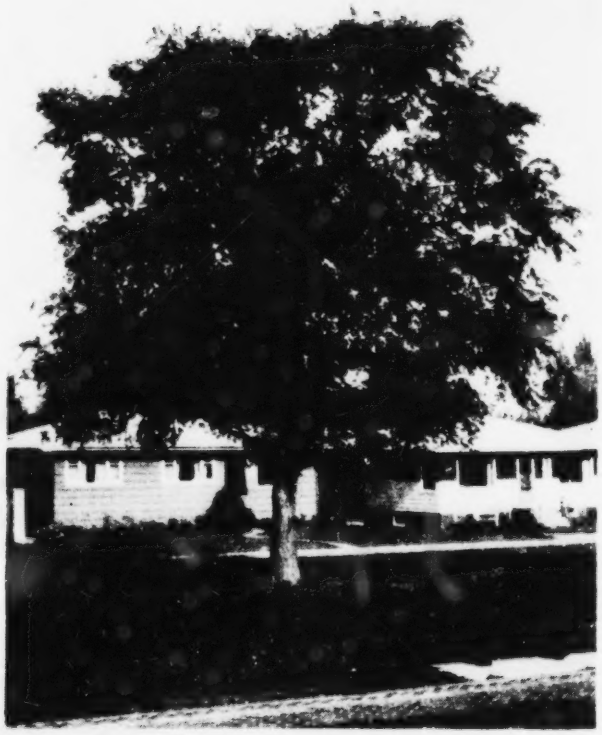
GREEN ASH

Fraxinus pennsylvanica

Height to 15 m
Spread to 10 m
Root Spread - 2.4 h
Growth Rate - medium
Zone - 2b to 9
Chinook Hardy

One of the most common boulevard trees with an upright oval shaped crown, good branch structure

Elm as a boulevard planting

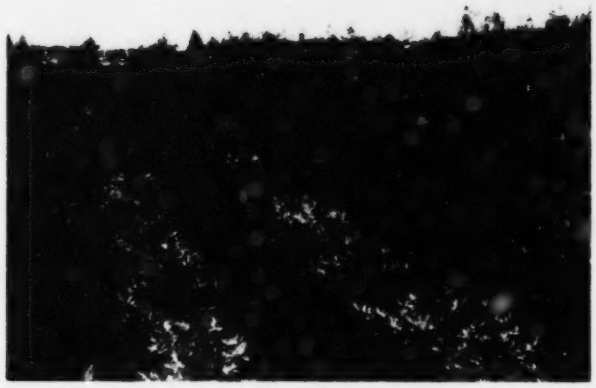


Manchurian ash (*Fraxinus mandshurica*)

American elm (*Ulmus americana*)

American elm (*Ulmus americana*)

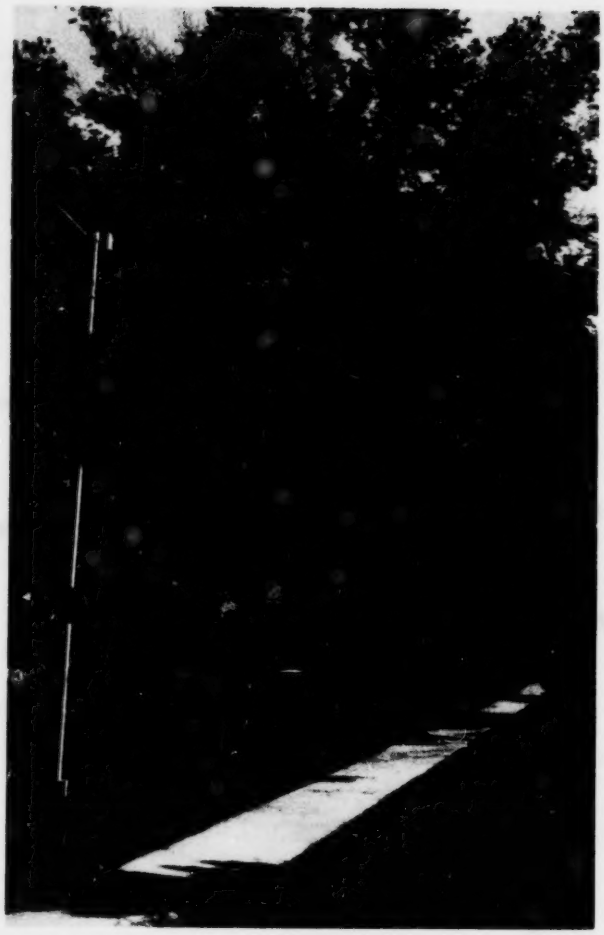
Street planing of birch (*Betula* sp.)



Nursery production of trees

Ussurian pear (*Pyrus ussuriensis*)

Recently transplanted tree



Decaying maples in street planting (*Acer negundo*)

Laurel leaf willow (*Salix pentandra*)

Silver maple street planting (*Acer saccharinum*)

Burls on Manitoba maple (*Acer negundo*)

and few problems. Male seedless selections are liable to have ash flower gall mite, while seeds on the female trees are a nuisance.

There are a few selections available, the better one being 'Patmore', while 'Summit' and 'Marshall's Seedless' are of borderline hardiness.

WHITE SPRUCE

Picea glauca

Height to 15 m
Spread to 5 m
Root Spread - 1.0 h
Growth Rate - slow
Zone - 1b to 9
Chinook Hardy

This conical native evergreen prefers moist soil. Needles dark green, sometimes with a bluish cast. Subject to Cooley gall aphid and yellow headed spruce saw-fly attacks. Sensitive to deicing salts.

SCOTS PINE

Pinus sylvestris

Height to 15 m
Spread to 7 m
Root Spread - 2 h
Growth Rate - fast
Zone - 3 to 9

Pyramidal when young but irregular or flat topped when mature with orange bark. Needles are paired and blue-green in color. Sensitive to deicing salts. Prefers moist, well-drained soils.

TOWER POPLAR

Populus x canescens 'Tower'

Height to 12 m
Spread to 1.5 m
Root Spread - 2.4 h
Growth Rate - fast
Zone - 2b to 9
Chinook Hardy

This relatively recent introduction from Morden, Manitoba is tall and narrow. Leaves are a shiny dark green when mature with silver undersides, but are light brown when young. This tree appears to be very hardy and can be effective for screening.

SWEDISH ASPEN

Populus tremula erecta

Height to 12 m
Spread to 2 m
Root Spread - 4 h
Growth Rate - fast
Zone - 2 to 9
Chinook Hardy

This tall narrow tree is one of the parents of the 'Tower' poplar and quite similar in appearance, however, the leaves are medium green. Again an effective screening plant.

AMUR CHERRY

Prunus Maackii

Height to 12 m
Spread to 8 m
Root Spread - 4.0 h
Growth Rate - medium
Zone - 3
Chinook Hardy

A flowering tree with a papery bark of a bronze color. Although the fall color is yellow, the inner leaves turn first. The wood tends to be soft and frost cracks are common. The bitter small black cherries are readily eaten by birds.

BUR OAK

Quercus macrocarpa

Height to 12 m
Spread to 10 m
Root Spread - 4 h
Growth Rate - slow
Zone - 2
Chinook Hardy

A long-lived tree with a round headed crown when mature, but cone shaped when young. The branching habit is good, the mature bark is dark grey and deeply furrowed and the tree has a strong tap root. The fruit is an acorn up to 2 cm long, and is dropped in fall. These can be a problem in lawn maintenance but they are readily eaten by birds and squirrels.

WILLOWS

Salix sp.

Height to 15 m
Spread to 15 m
Root Spread - 4 h
Growth Rate - fast
Zone - 1b to 9
Chinook Hardy
(Selected sp.)

A variable group, most with upright to round headed crowns. The wood tends to be brittle. Young twigs tend to be colored. Grows well in wet areas and poor soil, intolerant of dry street conditions.

SIBERIAN ELM

Ulmus pumila

Height to 12 m
Spread to 8 m

Amur cherry (*Prunus mackii*)

Amercian linden or basswood (*Tilia americana*)

Bark of Amur cherry

Littleleaf linden or basswood (*Tilia cordata*)

Root Spread - 4 h
Growth Rate - fast
Zone - 2b to 9
Chinook Hardy

The Siberian or Manchurian elm has a broad round head with a better branching habit than the American. Smaller branches and young twigs tend to get shed in wind storms and seeds can be a problem.

TALL TREES

SILVER MAPLE

Acer saccharinum

Height to 25 m
Spread to 15 m
Root Spread - 2 h
Growth Rate - fast
Zone - 3b to 9

The trees will tolerate adverse conditions but tend to be weak wooded. Problems are few in Alberta because the trees are limited to only the most favorable cities - Edmonton and Medicine Hat.

WHITE ASH

Fraxinus americana

Height to 20 m
Spread to 20 m
Root Spread - 2.4 h
Growth Rate - medium
Zone - 3b to 9

An uncommon ash of doubtful hardiness in most areas. Susceptible to the ash flower gall mite. Seeds are a problem on female trees.

SIBERIAN LARCH

Larix sibirica

Height to 20 m
Spread to 8 m
Root Spread -
Growth Rate - medium
Zone - 1b to 9
Chinook Hardy

This tall conical deciduous conifer has light green bundles of needles which are shed after turning yellow in the fall. Prefers moist, well drained soils.

COLORADO SPRUCE

Picea pungens

Height to 25 m
Spread to 10 m
Root Spread - 0.8 h
Growth Rate - slow
Zone - 2 to 9
Chinook Hardy

A broad conical coniferous tree which varies in color from green through a grey blue (Glauca). Prefers moist, well drained soils. Sensitive to deicing salts and can be attacked by spidermites.

PONDEROSA PINE

Pinus ponderosa

Height to 20 m
Spread to 8 m
Root Spread - 2 h
Growth Rate - fast
Zone - 3b
Borderline Hardiness

Pyramidal evergreen with two or three long dark green needles per bundle. Older bark is orange-brown and scaley. It prefers well drained soils but can tolerate poor conditions. Sensitive to deicing salts.

POPLARS

Populus sp.

Height to 20 m
Spread to 15 m
Root Spread - 4.0 h
Growth Rate - fast to very fast
Zone - 2 to 9
Chinook Hardy

A large and variable group of trees. Many of the common poplars, such as 'Northwest' and 'Brooks #6' are hybrids and tend to be short lived in crowded conditions. They are good trees for screening and park plantings where space is not limited.

Problems are many: female trees produce cotton, Northwest is liable to be affected by poplar bud gall mites (a serious problem south of Calgary), cankers develop when the trees are put under stress such as drought, heavy pruning, root disturbance and old age. Suckers can be a problem, especially after roots have been wounded. Although it has the bad reputation of blocking sewers it is no worse than other plants.

Several cities have special regulations regarding the use of poplar. For example:

- Edmonton and Lethbridge do not plant poplar on boulevards. Use is restricted to parks.
- Lethbridge is recommending that poplar be replaced with more suitable species.
- Red Deer uses poplar only on boulevards with a minimum width of 11.5 m.
- Calgary is phasing out poplar on residential and collector street boulevards.

Shubert chokecherry (*Prunus virginiana melanocorpa*)

May Day tree (*Prunus padus commutata*)

Street planting of Mountain ash

Mountain ash (*Sorbus* sp.)

Mountain ash flower

These use regulations have evolved because of problems the various centres have experienced over the years. The problems have generally been in the area of root sewer conflicts, roots heaving walkways and lawns and the more frequent need for pruning. The regulations are a reaction to the problems and single out the poplar as difficult species for urban use.

AMERICAN LINDEN

Tilia americana

Height to 20 m
Spread to 12 m
Root Spread - 2 h
Growth Rate - medium
Zone - 3 to 9

The American linden, or basswood, is an imposing cone shaped tree. Growth habit is usually good with only an occasional narrow angled branch. The flowers appear in late June, are not obvious but have a pleasing scent. The bark is grey with only shallow furrows. Suckers are liable to develop at the base and mites can cause tear shaped galls on leaves of younger trees. The tree requires more water than usual and is intolerant of deicing salts.

LITTLELEAF LINDEN

Tilia cordata

Height to 18 m
Spread to 12 m
Root Spread - 2 h
Growth Rate - medium
Zone - 3 to 9

A round headed tree with a smooth orange colored bark when young. Likes moist soil and is also intolerant of roadside salts.

Selection from crosses of the Littleleaf and American have better habit, hardiness and growth rate, the best one being the 'Dropmore'.

AMERICAN ELM

Ulmus americana

Height to 25 m
Spread to 15 m
Root Spread - 4 h
Growth Rate - fast
Zone - 3 to 9
Chinook Hardy

This is the most common boulevard tree in Alberta with a graceful, arching vase-shaped crown with narrow angled branches. Heavy seed set can occasionally be a problem and large populations of aphids cause 'honey dew'.

American elm is susceptible to Dutch elm disease, which has almost wiped out the elm in most areas of North America. It is not yet present in Alberta, but is causing serious problems in native stands in Manitoba.

APPENDIX B

Spacing and Setback Recommendations for Street Trees

I.Distance Between Trees

Size	Minimum Spacing (metres)
Small-growing	4.5 m
Medium-growing	6.0 m
Large-growing	8.0 m

* Refer to Appendix A for tree size ratings.

II.Setbacks - All Species

	Minimum Distance (Metres)
Distance from Corner	7.5
Distance from Light Poles	3.5
Distance from Fire Hydrants	3.5
Distance from Stop Signs	3.5
Distance from Yield Signs	3.5
Distance from Bus Stops	2.0
Distance from Other Signs	2.0
Distance from Driveway	2.0
Distance from Crosswalks	2.0
Distance from Sidewalks	2.0
Distance from Underground Utilities	1.0 - 2.0 m (depending on utility)

APPENDIX C

Agencies and Organizations that can Assist Street Tree Programs

Federal Government

Northern Forest Research Centre
Canadian Forestry Service
Environment Canada
Edmonton, Alberta

Provincial Government

Alberta Tree Nursery and Horticulture Centre
Alberta Agriculture
Edmonton, Alberta

Alberta Horticultural Research Center
Alberta Agriculture
Brooks, Alberta

Private Organizations

Alberta Association of Landscape Architects
Larry Paterson, President
Lombard North Group (1980) Ltd.
201, 239 - 10th Avenue, S.E.
Calgary, Alberta T2G 0V9
264-4433

Landscape Alberta Nursery Trades Association
10215 - 176 Street
Edmonton, Alberta T5S 1M1
489-1991

Urban Development Institute
P.O. Box 5424
310 Kingsway Garden Mall
Station "A"
Edmonton, Alberta T2H 1X8
471-6551

APPENDIX D

Members of the Trees in the Urban Landscape Committee

Mr. Henry Heuver	Chairman, Landscape Alberta Nursery Trades Association
Mr. Lawrence Paterson	Alberta Association of Landscape Architects
Mr. Herman Oosterhuis	Alberta Agriculture Alberta Tree Nursery and Horticulture Centre
Mr. Brendan Casement	Alberta Agriculture Alberta Horticultural Research Center
Mr. Ray Nyroos	City of Edmonton Parks and Recreation
Mrs. Liane McKenna	City of Calgary Parks and Recreation
Dr. Herb Cerezke	Environment Canada Northern Forest Research Centre
Mr. Al Barclay	Landscape Alberta Nursery Trades Association

REFERENCES

Arnold, H.F. 1980. Trees in Urban Design. Van Nostrand Reinhold Co., Toronto: 168 p.

Busgen, M and E. Munch. 1929. The Structure and Life of Forest Trees, Third Edition, T. Thomson Trans. John Wiley and Sons Inc., New York: 436 p.

Carpenter, P.S. 1983, Residential Landscaping II, Planting and Maintenance. PDA Publishers Corporation, Mesa Arizona: 143 p.

Carpenter, P.S. Walker, T.D. Lanphear, F.O. 1983 Plants in the Landscape, W.H. Freeman and Company, San Fransico.

Cutler, D.F. and I.B.K. Richardson. 1981 Tree Roots and Buildings. Construction Press, London: 94 p.

Elias, T.S. 1976. Trees and the Community. New York: The Cary Arboretum of New York Botanical Garden.

Fayle, D.C.F. 1968. Radial Growth in Tree Roots, Fac. of Forestry, University of Toronto Tech. Rep. 9: 1-183.

Grainger, G. 1982. Determining Replacement Value of Trees and Shrubs in Alberta - A guide to assist professionals. Alberta Agriculture.

Harper, D.E. 1983 Trees and Towns (Technical Paper Series 5), British Columbia Heritage Trust - Heritage Conservation Branch, February.

Hoag, D.G. 1975. Trees and Shrubs for the Northern Plains, North Dakota, Institute for Regional Studies, Fargo.

Hopkins, G. (Coordinating Editor). 1978. National Urban Forestry Conference Proceedings: Vol. II, Session II and III, State University of New York, College of Environmental Science and Forestry, Syracuse, New York: 874 p.

Johnson, C.G. McPherson, S. Gutting. 1982. Community Forestry Manual for the Cities and Towns of Utah and Southern Idaho. Cooperative Extension Service, Utah State University. Logan, Utah.

Knowles, R.H. 1975. Woody Ornamentals for the Prairie Provinces, University of Alberta, Faculty of Agriculture and Forestry, University of Alberta, Bull. No. 58.

Kramer, P.J. and T.T. Kozlowski, 1960 Physiology of Trees. McGraw-Hill Book Company, Inc., Toronto. 642 p.

Little, S. and J.H. Noyes (Editors) 1971, Trees and Forests in and Urbanizing Environment. Symposium held August 18-21, 1970. University of Massachusetts, Amherst. Monograph, 168 p.

Lyr, H. and G. Hoffmann. 1967. Growth Rates and Growth Periodicity of Tree Roots. Int. Rev. for Research, 2: 181-236.

Oosterhuis, H.T. 1983. Shelterbelt Planting and Farmstead Beautification, Alberta Agriculture, Agdex 271/17-1.

Perry, T.O. 1982 The Ecology of Tree Roots and the Practical Significance Thereof. J. of Arboriculture. 8: 197-211.

Piore, P.P. 1972. Tree Maintenance, Oxford University Press, New York.

Phillips, L.E. Jr. 1981. Municipal Street Tree Master Planning, Peabody, Mass., Park Maintenance Technical Standards Manual, City of Edmonton Parks and Recreation.

Prince, C. 1981. Trees in the Alberta Urban Landscape, Present Day Practices and Problems. Trees in the Urban Landscape Committee, Edmonton.

Robinette, G.O. 1972. Plants/People and Environment Quality, U.S. Department of the Interior, National Park Service, Washington, D.C.

Stahlmann, G.W. (Compilor). 1981. Trees for the Urban Environment. Ontario Shade Tree Council: 17 p.

Stout, R.F. 1969. Form and Development of Conifer Root Systems. Commonwealth Forestry Bureau, Tech. Comm. No. 7, London: 1-131 p.

REFERENCES

Stout, B.B. 1956. Studies of the Root Systems of Deciduous Trees. Black Rock Forest Bull. No. 15: 1-45 p.

Sullivan, R.H., R.S. Gemmell; L.A. Schafer and W.D. Hurst. 1977. Economic Analysis, Root Control, and Backwater Flow Control as Related to Infiltration/Inflow Control. American Public Works Association, Chicago Ill.; U.S. Department of Commerce, Nat'l Tech. Inf. Service PB-280738: 102 p.

Sutton, R.F. 1969. Form and Development of Conifer Root Systems. Commonwealth Forestry Bureau, Tech. Comm. No. 7, London: 1-131.

Torrey, J.G. and D.T. Clarkson, (Editors). 1975. The Development and Function of Roots, Third Cabot Symposium. Academic Press, New York:

618 p.

Van Eerden, E. and J.M. Kinghorn (Editors). 1978. Proc. of the Root Form of Planted Trees Symposium. British Columbia Ministry of Forests/Canadian Forestry Services Joint Rep. No. 8, Victoria, B.C.: 357 p.

Weiner, M. 1975. Plant a Tree. Collier Books. New York.

Wile, B.C. 1978. Hardy and Pollution Resistant Trees and Shrubs for Urban Areas and Roadsides in the Maritimes. Maritimes Forest Res. Centre. Fredericton, N.B., Inf. Rep. M-X-88: 6 p.

Zimmerman, M.H. and C.L. Brown. 1971. Trees, Structure and Function.

Springer-Verlag, New York. 336 p.

Canadian Nursery Trades Association. Guide Specification for Nursery Stock.

The Prairie Garden. Winnipeg Horticultural Society. P.O. Box 517, Winnipeg, Manitoba, (Gardening Annual for Western Canada).